THE LIFE AND WORK
of
JAMES LEON WILLIAMS

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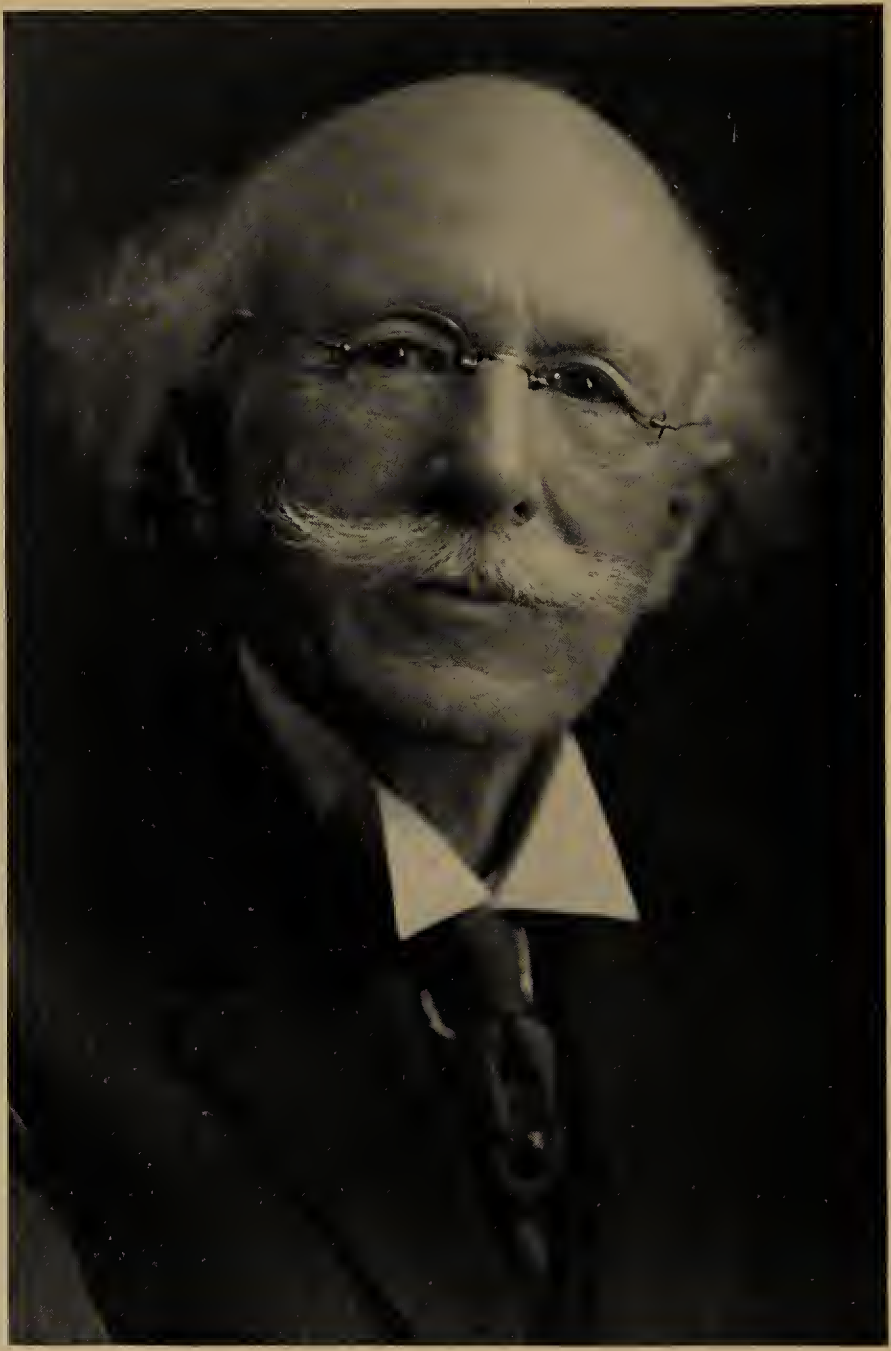

J. Leon Williams

THE LIFE AND WORK *of* JAMES LEON WILLIAMS

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BY
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With Introduction by
C. N. JOHNSON, M. A., D. D. S., F. A. C. D.
President of the American Dental Association.

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DEDICATION

This book is dedicated to all in the dental profession who are young in heart and mind. It is the story of a life which found in dentistry an open door to achievements that far outran the practice of the day and that have benefited every practitioner who has applied their results and every patient for whom the results have been applied.

May what Dr. Williams has done inspire every dentist with the conviction that when he has made himself a big enough man to be a good dentist he will be big enough also to take a constructive part in the development of a healthy and happy community life!

May youth be no damper to ambition and age no barrier to achievement!

APPRECIATION

Few lives in the dental profession present such a wealth of interesting and instructive material as Dr. Williams's. He has unswervingly applied an unusual mental endowment to the discovery and announcement of the truth. The facts that the first dozen years of his professional life were spent in obscurity and in unceasing studies and labors which were to prove merely preparatory to bigger things and that at the age of seventy years, and in spite of ill health, Dr. Williams did some of his best work should encourage young men to hold steadily onward through difficulties and apparent failure until they have made themselves ready for success. To use his words, they should "listen to the inner voice."

For about fifteen years the writer has been intimately associated with him of whom he writes. During that time research work of a difficult and tiresome kind has been continuous. Much of the work has been in new fields, with the goal not clearly in sight, and progress has been slow.

It takes a fine mind and character to stand such an acid test for so long a time. He has stood it well. And the writer is glad to offer this work, while Dr. Williams is still with us, as an evidence of his respect, admiration and affection.

G. W. C.

INTRODUCTION

The biography of a great and good man is always an interesting document. This is particularly true if the man, in addition to being great and good, chances to be endowed with those cultural graces which lend tone and distinction to his career. It is also a fortunate circumstance if the biographer chances to be not only a friend but a close companion of the man of whom he writes and is thus thoroughly familiar with all the varying influences which have contributed to his achievements. In the present volume there is a most happy combination of these conditions, and we may therefore look for the best possible presentation of the significant factors in the life of the subject of the treatise.

Dr. Clapp brings to his task not only an intimate knowledge of his theme but a loyal devotion and a veneration for Dr. Williams which could not fail to be vividly transferred to the printed page; and he has given us in this book such a portrayal of the leading characteristics of his friend that the reader is unconsciously led to absorb much of the enthusiasm and admiration which form the mainspring of Dr. Clapp's effort.

In some respects this is a remarkable book. It portrays the most significant activities of a man who has exhibited a wider diversity of talent than is usually vouchsafed to a single individual, and it has emphasized the salient features in a most discriminating way. In perusing this volume the reader is struck with the amazing versatility of the subject. Dr. Williams seems equally at home with the microscope, the pen, the palette, and the graver. He is at once a student, a writer, a scientist, an artist, and a sculptor. Above all, he is a philosopher. In writing the biography of a man of this wide range of ability it might naturally be expected that the author would at times indulge in extravagant statement—in fact, it might seem pardonable for him to do this. But Dr. Clapp, with all his manifest admiration for Dr. Williams, has not done so. He has taken the safer and saner course of letting Dr. Williams speak mostly for himself by reproducing many of his outstanding papers and has contented himself with merely connecting them up in an orderly sequence.

When one studies the life work of Dr. Williams as here portrayed, one is amazed. He seems to tower as an intellectual giant in any one of the various activities which have engaged his attention in the past half a century. In the first place, he began early in life to absorb that kind of literature which laid the foundation for his future philosophical and scientific studies. When a man, before he is twenty-five, has made himself familiar with the works of such authors as Ruskin, Emerson, Swedenborg, Spencer, Darwin, Huxley, Tyndall, John Fiske, etc., he has chosen a diversified and rather heavy diet, and one which is well calculated to destroy effectually his appetite for ephemeral literature.

It is difficult to say in which branch of study and investigation Dr. Williams shines brightest. Surely in his scientific work his theories command instant attention, particularly in his research on the characteristics of enamel and the beginning of caries in this structure. The illustrations used in his study of enamel are most excellent and should claim the attention of every dentist and scientist. The design of nature in building enamel for the special purpose to which it is to be subjected in usage is vividly illustrated in a section from the enamel of the beaver—an animal which probably puts the teeth to severer tests than any other. The arrangement of the enamel rods in the beaver's tooth is a striking example of the wondrous mechanism which nature provides to meet the demand of environment. Some of these sections are finer than anything we have ever seen before, and they will appeal particularly to all who are interested in dental histology.

But why try to particularize in calling attention to the outstanding achievements of Dr. Williams's life? A true perspective can be gained only by reading the book, and to this pleasant and profitable task everyone is invited into whose hands it may fall. If the present writer were permitted to express his own preference as to the topics treated in this volume he would be obliged to acknowledge that his interest has been more insistently gripped by the discourses on philosophical and ethical thought than by the many splendid things that Dr. Williams has written on other subjects. It is impossible not to think seriously and constructively after reading this part of the book, and in the present age of social and moral unrest it is a very salutary thing for every responsible individual to do some thinking.

From every point of view Dr. Clapp has given us a work of real value and one which will place the profession under lasting obligation to him.

The personal wish is herewith expressed that Dr. Williams may be permitted to live for many years to come to lend the influence of his great ability and his mature judgment toward the solution of the many pressing problems of our profession.

C. N. Johnson

Chicago, Ill., 1925.

Made in U. S. A.

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PART ONE

ANCESTRY AND CHILDHOOD

PREFACE TO PART ONE

Oliver Wendell Holmes once jokingly remarked that the education of a child ought to begin about two hundred years before the child is born. What Holmes said in jest science now says in earnest, only instead of "ought to begin" it writes "begins" and instead of "two hundred years" it writes "two hundred thousand years."

And then it produces plausible evidence that the capacity of a mind is inborn, bequeathed to it by the mentality of ancestors, the story of whose hard-won development goes back so far as to make the earliest dates in authentic history seem but yesterday. Science holds the environment responsible for stimulating the mind to action and furnishing material for it to work upon.

Under these conditions no biographer who wishes to present anything approaching a true picture of a life characterized by constructive mental action can omit from the story at least a brief account of the ancestral strain and of the childhood during which the beginnings of the principles and purposes which were to guide the life were being graven into the plastic mind.

CHAPTER I

THE WILLIAMS FAMILY AS PIONEERS

IN the year 1785 Captain Jacob Williams, ex-soldier, drove a bateau up the east branch of the Kennebec River, in what was then the Province of Maine, to a spot a mile above Caratunk Falls. There he found a pleasant intervale and "took up" a thousand acres of land.

It was an historic spot. Less than ten years before, Arnold, with eleven hundred men in two hundred bateaux, had gone that way on his march to attack Quebec, perhaps the most desperate and dangerous march ever made to attack an enemy. Caratunk Falls had been the first serious obstacle on that march. They had portaged boats, supplies and ammunition around the falls and gone on their indomitable way. Williams must have thought of this as he portaged his scanty belongings.

He knew a bit about history because he had helped make it. He was a native of Massachusetts. His boyhood had been spent in the rapids of the thought-current which finally separated us, politically, from Great Britain. He had fought his way through the Revolution with sufficient distinction to rise to the rank of captain. Now he was to help make another kind of history by his part in carving a great state out of a wilderness.

To a less venturesome spirit the difficulties and dangers attending the new enterprise would have appeared hardly less than those he had sustained during the war. Except for the intervale the land for miles in every direction was primeval forest. There were no roads. The Indians were hostile. Some of the animals were dangerous. There were no near neighbors, and no one to help in time of difficulty. Truly, he was to hold life and fortune by his own vigilance and courage.

For two years he labored diligently. The little clearing of the intervale was extended and a small log cabin was built. Then he returned to Massachusetts and brought his wife and two children to the place which was thenceforth to be home. Some idea of the isolation may be formed from the fact that the nearest mill at which wheat or corn could be ground into flour or meal was fifty miles away. The grain was carried in sacks on the horse's back along bridle paths through the forest. The man walked, carried his gun and watched. Passage was so difficult that even the sturdy pioneers required a week for the round trip.

But adventure is the natural diet of the venturesome, and the family thrived and grew. In the log house, about 1794, was born Richard Williams, who was to be the grandfather of J. Leon Williams.

Work was the continuous portion of everybody above the age of childhood. Gradually the margin of the wilderness was pushed back. As each boy married, Captain Jacob gave him a 100-acre farm, and soon there was a goodly settlement of Williamses.

* * *

The house which Captain Jacob's son Richard built about thirty-five years after the building of the first cabin marked a great advance over the home place because it was sheathed with boards sawed at a mill which had recently located only a few miles away. The shingles, however, were split by hand from cedar and were trimmed to shape with drawknives. They were about three feet long, and their quality may be judged from the fact that many of them remained in good condition and in their original position for nearly half a century. In this house, on May 25, 1829, was born Calvin Williams, the father of J. Leon Williams.

Even at the time of Calvin Williams's birth the conditions of life were primitive. It was to be almost half a century to the discovery of kerosene, and the tallow candle was still in the future. Light was obtained from the fireplace or by immersing a rag in a shallow dish filled with grease and setting fire to the rag. The flintlock rifle was the weapon of defense.

Probably partly on account of the hostility of the Indians the making of moccasins appears not to have been learned in the early days. Boots were rare and precious and were worn only on state occasions, since it was essential that each pair should last several years. In pleasant weather, when religious services were to be held, each member of the family possessing boots carried them suspended about the neck by a string until near the church. They were then put on and worn during the service. They were removed as soon as seemed proper after leaving the church, and the family walked home barefoot. One fancies that many a man whose feet were accustomed to the freedom of all outdoors throughout the week must have suffered through the two- and three-hour sermons and heaved a sigh of relief when, the service over and in the shelter of the friendly woods, he could take his boots off, hang them about his neck and again wiggle his toes in freedom. This must have been true of the boys in particular, since each boy was expected to wear a pair of boots until he so far outgrew them that by no exercise of physical force could he get them on.

When the weather became too cold for them to go barefoot, they wrapped their feet in whatever they could apply. In a climate where the winter is as long and as bitter as often in Maine it was necessary to get in an ample store of wood for the open fire. It was often impossible to get this all cut up before the winter storms came on. When obliged to cut wood in the winter, each cutter would stand a piece of oak plank about two feet square in front of the open fire until it was thoroughly warmed. He would then rush with the plank to the place where he was to cut the wood and stand on it until he got so cold that he could no longer work. By repetitions of heating and chopping the winter's store of wood was kept up.

* * *

The river which had been Captain Jacob's road into the country was also an important source of food. Fish was abundant, and in the deep channel below Caratunk Falls, in the proper season, a boat could be filled with salmon in a single night. The fish, when salted, formed an important part of the diet in many families throughout much of the year. In fact, the diet became so continuous and monotonous that many years later a law was passed that no apprentice should be required to eat salmon more than three times a week. But there was no such law in the early days. It was then sometimes salmon or nothing!

At certain seasons game was abundant. Moose, deer, bear, catamounts and smaller game helped to supply the table and probably furnished the young folks with sport. Captain Jacob once shot a moose without leaving the cabin, merely by putting his gun through the window. And many years later, when the planting of orchards began, it was sometimes difficult to protect the young trees from the deer. Wild ducks and geese were plentiful. The geese provided not only food but feathers which were valuable for beds. If there ever was not only an excuse but a fitting place for a feather bed, it must have been in a fireless chamber when the temperature outside was forty degrees below zero!

The Williams Coat of Arms.

CHAPTER II

BOYHOOD DAYS

WHEN Captain Jacob Williams settled his family in the little intervale above Caratunk Falls, he became an outpost of civilization, not merely a place from which it could move forward of its own momentum but a dynamic force to help it forward in ever widening circles. In doing this he was merely carrying out the traditions and practices of his race and family. He was descended from that sturdy English middle class which for centuries had stood valiantly and with ever increasing effectiveness for the conception of its legal rights and freedom to worship God according to the dictates of its own conscience.

Probably the most famous member of the Williams family was Oliver Cromwell, who was born a Williams. This now almost forgotten story runs as follows. A certain Richard Williams rose to fortune in England through the favor of the Earl of Essex, whose name was Cromwell. As an expression of gratitude, Richard Williams gave to his son Henry the name of his protector—a not uncommon practice in those days—and he became Sir Henry Cromwell. To Sir Henry Cromwell and his wife Elizabeth (said to have been a member of the royal house of Scotland) there was born in 1599 a son, Oliver Cromwell, who later became the champion of the rights of the middle class and Lord Protector of England.[1]

Evidently the spirit of independence and rebellion as manifested by the Williams family did not die with Oliver Cromwell. When Roger Williams reached the Massachusetts colony and found that middle-class Englishmen had there become quite as dictatorial in matters of religious belief as ever the ruling class in England had been, he rebelled to such effect that he was thrust out of the colony because of his religious convictions. He carried his convictions concerning the brotherhood of man into effect when he founded Providence Plantations, now the State of Rhode Island, where he and his colonists lived for many years in much more amicable relations with the Indians than did his more dictatorial neighbors. And Providence Plantations presented to the world the first opportunity, in any land under control of the Anglo-Saxon race, for every man to worship God as he saw fit.

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[1] From *The Dictionary of National Biography.* The essentials of this statement are concurred in by *The Encyclopedia Britannica.*

Other members of the Williams family played conspicuous historical parts in the liberation and development of the new country that was just coming into being. Among them may be mentioned Captain Samuel Williams, who fell at Lexington; Lieutenant Williams, an officer at Bunker Hill; David Williams, one of the captors of André who refused a liberal bribe for his release; William Williams, a signer of the Declaration of Independence; and Elisha Williams, who bore an important part in the development of Yale College.[1]

Many of the inherent characteristics of his race must have come unconsciously to Captain Jacob as part of his family heritage. His own experience had done much to develop some of them. And so, when he hung his gun on the pegs by the fireplace, he placed his Bible on the rude mantel-shelf. Literally, he was to live by both. There were three dicta in that home: unfailing courage, unceasing industry, unswerving faith in God. These were the sinews of the intellectual and moral life.

* * *

Calvin Williams had spent some years of his early life in Massachusetts. While there, he had fallen under religious influences somewhat more liberal than the stern Methodism in his father's home. After his return to Maine he was so fortunate as to become acquainted with a family of a type similar to his own, and, while paying attention to Miss Susan Wells, he became a great admirer of her father and her aunt, both persons of unusual mental attainments. Their religious views were profound but liberal, and under their influence Calvin Williams became a Universalist. He married Susan Wells, and of this union James Leon Williams was born on April 21, 1852. He was the eldest of eight children, six boys and two girls. We get an interesting side light on the continuance of rather primitive and certainly severe conditions of life nearly seventy years after Captain Jacob's landing from the fact that it was deemed advisable for the mother to go to her mother's home at Embden for the event.

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[1] As this book was going to press, Dr. Williams received from C. C. Williams, M.D., of Los Angeles, California, a letter having to do with the genealogy of the Williams family, of which the following is a part:

"For several years I have been compiling a record of descendants of Richard Williams of Taunton, b. 1606, d. 1693, whose ancestry is traced in England and Wales in a direct line to 740 A. D. Oliver Cromwell and Richard Williams had a common ancestor.

"Jacob Williams of Barnstable, Mass., settled in Caratunk, and his descendants were many in Concord, Embden, Anson and Madison.

"Jacob's father was Ebenezer of Easton, who was son of John. John was son of Benjamin, and he was the youngest son of Richard and Frances (Dighton) Williams, both of distinguished ancestry. Jacob m. Joanna Williams, also from Richard by his oldest son, Samuel."

The habits of the Williams family favored the development of wisdom in the thinking members of such a race. Wisdom is the judicious use of knowledge and is quite as likely to result from limited knowledge used often and well as from more extended knowledge less well used. Books were few. Even in families where they were highly prized the library usually consisted of the Bible, the writings of Josephus, *Pilgrim's Progress* and a volume or two of sermons. The widely flung postal system of the present day was far in the future. The daily paper was, of course, unknown in rural communities. Eighty years after Captain Jacob built the first cabin the Williams family was favored above most because Calvin received weekly *The Maine Farmer* and to Susan Williams came *Godey's Lady Book* once a month.

During the summer there was not much time for reading, but in the winter darkness came early. After the stock was attended to and the wood in, there was ample time for reading, study and discussion. In the Williams family the books were not merely read—they were assimilated. God became to them almost what He had been to Abraham—a reality, a friend and a factor in the daily life. Each event, each personage in every book was discussed from every angle. Grandfather Williams lived with his son Calvin. Between the stern Methodism of the one and the

Universalism of the other it is not surprising that Leon's strongest childish memory should be of nearly endless discussions on the subject of religion.

* * *

The books in the tiny library were schoolbooks for the children. Leon learned the letters of the alphabet from the family Bible, standing beside his grandfather's knee. At the age of four, with grandmother's constant assistance, he haltingly read *Pilgrim's Progress.* By the time of Leon's boyhood schools were numerous, and at the age of five he went to the "little red schoolhouse" a mile and a half from the farm. When the children had progressed beyond the limits of instruction there, they went to Solon, walking four miles twice a day. During the spring and fall this journey was pleasant enough, but in winter it frequently happened that no teams passed to break the road for a week or two and the children had to make their own way through deep snow. This, when it was at all possible, they regarded as more of an adventure than a hardship.

One of the formative events in Leon's life occurred while he was in the Solon school. His father gave him Comstock's *Philosophy,* which presented the fundamentals of natural philosophy in a readable way. The beginnings of the elective educational system are shown in the fact that, although this was the only copy in the school, he was permitted to form a class all by himself and give it thorough and painstaking study.

* * *

The most advanced disciples of what we call "modern science" tell us that the impressions registered during childhood sink deep into the fiber of our lives and that our daily acts are influenced by them far more than we realize. Certainly this happened with the Williams children. While Leon was still a rather young boy, his father brought him one of his first personal belongings, a little shotgun. The one restriction was that under no conditions was it to be fired on Sunday.

The Road to Solon.

From a photograph colored by Mrs. J. Leon Williams.

One Sunday, when the boys had become fairly expert in the use of the gun, the parents went to spend the day with friends, leaving the boys at home. There was not much for them to do, and Leon and a brother wandered idly about seeking some sport not forbidden on the Sabbath. As they were going through a field, a flock of partridges alighted on a tree near by and the boys went over, expecting them to fly away immediately. Curiously enough, they did not fly, and the boys got almost up to them. The thought came as to what a killing they could make if only they had a gun. But it was Sunday. Shooting was absolutely forbidden and punishment would surely follow. The temptation was too great to be resisted—better the punishment than the loss of such an opportunity. The boys got away quietly, ran to the house, loaded the gun and returned to the tree. As before, the birds remained quiet. Leon cocked the gun, put it to his shoulder and looked along the barrel at the birds scarcely twenty feet away.

And then there came to his mind some of the stories of the kind then current. In those stories the good boys were nearly always rewarded. But even surer than the reward of the righteous was the punishment of boys who were disobedient to their parents. Something terrible always befell them. As Leon looked along the gun, there came this thought: "If I fire this gun, I shall be disobeying my father's express command regarding God's Day. As likely as not it will explode and blow my head off." He lowered the gun, put down the hammer and silently and sorrowfully, but dutifully, replaced it on its pegs.

* * *

The very lack of toys forced the children back on their own resources. They had to contrive most of their playthings and clothe each with a wealth of imagination to make up for its actual shortcomings. At an early age Leon began to make drawings of natural objects. Then he wanted to color them as he saw them in pictures and in nature. No paints were available. So he got red colors from the juices of the beet and sumac, green from the chlorophyll of the leaves, and other colors from the entire range of vegetables within his reach. With these he colored his drawings. It matters nothing now that the colors were weak and fugitive. It was the beginning of something that in another land and time were to be of interest and value to many.

* * *

One side of the ancestral farm bordered the Kennebec River. On an island in the river, not far from shore, a great tree had broken off, leaving a stump about thirty feet high. From the top of this stump Leon one day saw a duck fly. He knew that there were two kinds of duck, one which the boys called "wood duck," whose nests they occasionally found, and another which they called "wild duck," whose nests they had never found. He remarked to his younger brother that he believed a wild duck had a nest in that stump.

It did not take the boys long to contrive a raft and get across to the island. Leon immediately climbed the stump and saw in the top a nest containing thirteen eggs. He took off his soft hat, put the eggs into it, seized the edges of the hat between his teeth and got to the ground without breaking an egg.

A council as to the disposition of the eggs followed. The boys remembered that their mother had several hens sitting in the barn. They got to one of the nests unobserved, substituted the newly found eggs for the hen's eggs and awaited developments. Nothing happened for so long that they had nearly forgotten the incident when one morning they were aroused by a great clamor in the yard and the calls of their father for mother. They hastened to the yard and there found the old hen leading thirteen wild ducklings about. The story then came out and aroused such interest that people came from miles around to see a hen raising wild ducks.

But alas for the tragic ending! The old hen did not know how to get for them the particular kind of food they needed and they could not thrive on what she could provide. There was a pond not far from the barn and in her wanderings one day she took the ducklings near it. With the force of instinct and hunger combined they rushed into the water and began to feed on the tadpoles. The old hen, in great excitement, flew across the pond, but this availed her nothing. In her effort to fly back she fell in and Leon had to wade in to get her out. The ducklings, hungry and unrestrained, gorged themselves on the tadpoles so that before night every one of them was dead.

Years afterward Dr. Williams, when dining with John Burroughs and Henry Ford, told this story. At its close Burroughs said, "Well, Dr. Williams, I have heard a great many fish stories, both true and false, but that is the greatest duck story I ever heard."

CHAPTER III

A Youthful Escapade

WHEN the formative years of a normal childhood are spent in loving association with nature, one of two things is almost sure to happen. The non-aggressive mind will store up a great fund of knowledge which may give much pleasure throughout life. The intellectually aggressive mind not only will store the knowledge but will use it as the vehicle for the expression of the forces within.

There was probably nothing about Leon Williams, in childhood, to distinguish him from other children. But he was the lineal descendant of an aggressive strain in an aggressive race. His great-grandfather, Captain Jacob, had dared war, isolation, danger, hunger and toil. His grandfather and his father had followed along the trail which Captain Jacob had blazed. Now the dangers of wilderness-living were over, but the forces that had driven them bubbled up in Leon and were later to urge him to different forms of effort.

How truly is the child the father of the man! In Leon the intellectual power and aggressiveness of his father were blended with equal intellectual power on the part of his mother, to which was added a highly developed love of beauty and nature. It was said of her that she could make flowers grow when no one else could. In the words which a great florist was to utter many years later, she "loved them into growing." Looking back after more than half a century, it is easy to divide the activities of Leon's mind into two groups: one dominated by aggressive intellectuality, which had to take things apart to see what made them tick and then put them together again to make them tick better; and the other dominated by a love of philosophy and beauty in nature and art, which saw that all life is one harmonious whole, that it might be and ought to be beautiful, and that if one could only take away the disharmonies and errors, it would be a joy forever.

* * *

It might be thought that the rather limited environment of a New England farm would be a poor place to develop a love of nature, but such is not the case. Leon learned to watch with conscious delight the wonderful procession of the seasons, the disappearance of the snow on sunny banks in spring and the appearance of the first, spotted leaves of the fawn lily; to listen for the honk of the leader of the first flock of wild geese on their northward flight in spring; to see and hear the bobolink hovering over the buttercup-covered meadow, uttering in an ecstasy of delight the most liquid notes of birdland; to watch the whole retinue of birdlife through the summer and autumn until the arrival of the chickadee with the first fall of snow; to sniff the smell of the lilac and of the good brown earth at the first plowing; to thrill at the race with the coming thunderstorm at haying time; to enter with glee into the corn huskings and the apple-bees; to feel delight and a sense of awe at the brilliant display of northern lights on autumn and winter nights; and to sense that behind all this was something that antedated words but was closely akin to something in himself. He realized that the unrestrained responsiveness of childhood and youth to these and a thousand other things was a great blessing, and he sought to perpetuate it in himself and others. In adult life he came to realize that these experiences are the primal stuff out of which all religions and philosophies are made and that he who has missed them has missed the best that life has to offer.

* * *

When Leon was about fourteen years old, there occurred one of those incidents in family life which are always afterward looked back upon as sign posts on the road of development. The psychologists tell us that it is essential to the development of the manly character which is to succeed in life's battle that at the age of puberty the boy should assert his own personality and liberate himself from the sort of domination by parents which has marked his career up to that time. Leon had never heard of the psychologists, but he liberated himself in an effective way.

His father, though liberal in religious matters for his time, would now be regarded as unnecessarily strict. One Sunday, when he and his wife were going away to spend the day, they left Leon at home with instructions as to his conduct. All went well for a while, but when an older friend, Watson Thomas, came along with an outfit for tracking bees, Leon joined him in a journey to the woods in the hope that they might find a tree where the wild bees had a nest and a store of honey.

The outfit worked well and they had tracked wild bees about a mile and a half when they came to a stream where they found two boy friends fishing. Bee-tracking was abandoned and the four boys spent the day fishing and swimming. On their homeward way they arrived at the home of Watson Thomas just as Leon's father came over the hill from the other side toward the same place.

Leon's father, like many other good men, was temperamental, unduly lenient with his children at some times, unduly severe at others. In his severe moments the punishment often so far exceeded the requirements of justice as to create a sense of injustice in the minds of the children. Leon saw from a distance that his father was furious. He lagged behind the other boys. His father stopped for a few moments to express to the other boys, in a not very complimentary manner, his opinion of their kind of Sunday amusement. During this pause Leon slowly withdrew from the field of vision and soon reached the river bank and was hidden from sight.

As he went rapidly along the river toward home, the fear which had been the normal first reaction gave place to indignation at what seemed injustice. Out of this grew the decision that it was time for something to happen to change the course of events. It was now nearly dark and, unperceived, he reached the home barn and climbed to the haymow to think matters over.

When his father returned and Leon heard the substance of his talk with his mother, he immediately burrowed down between the mass of hay and the wall of the barn until he felt himself well hidden. His father came into the barn with a lantern and, after calling repeatedly, climbed to the mow and walked directly over the hidden boy, who, like Brer Rabbit, "said nothing and lay low." His father then descended and soon afterward went off down the road. Leon gladly came out of his stuffy quarters, but stayed in the mow to think over the new turn which matters had taken. He felt that he could not turn back now, but without money, clothes, food or means of transportation it was not easy for him to decide what was best to be done.

* * *

When darkness had well fallen, he came down from the mow with a plan matured. His friend of the day's adventure had a small boat at the river bank. He would get this, cross the river and go far away. As he made his way to the river, he saw numerous lights about the fields and banks. His father had aroused several of the neighbors to search for the boy, who might have been hurt in the woods or might have fallen into the river. Leon had some difficulty in running the gauntlet of lights on his way to the river, but there was no other course, since in the other direction the primeval forest stretched for hundreds of miles and no boy brought up as he had been would be foolish enough to enter it without taking ample precautions for getting out again.

He got to the boat, paddled across the river, not far from where his great-grandfather had portaged nearly a hundred years before, and landed on the other bank at what he thought to be about one o'clock in the morning. After tying the boat, he tramped steadily until nearly noon. He was getting well away from home, but not away from hunger. He had had nothing to eat for thirty hours.

When it seemed that he could go no farther, he saw a man shucking corn in the door of a barn. He approached him and asked for work. In reply to the farmer's questions he said that he wanted to work for his board and go to school. This was a common arrangement in those days and, after thinking it over a little, the farmer agreed and bade him help in shucking the corn. In about an hour, which seemed like an age to Leon, they were called to dinner. Leon heard afterward that the farmer said that never had he seen a person eat such a meal as that boy did that noon.

* * *

The second day after Leon's arrival the farmer went to town for part of the day without making any explanation of his trip. The next day, while he and Leon were working at pine stumps for the winter's kindling, Leon heard the rattle of a wagon at the top of a hill and, looking up, saw his father coming. He and the farmer were near the woods and Leon immediately took to his heels. He heard his father shout, "Stop that boy," but he was already on his way and beyond reach.

The farmer for whom Leon worked had a large dog of the mastiff variety. During Leon's stay he had, by dint of effort, established fairly good terms with the dog, who, under ordinary circumstances, might not have bothered him. But the shouting and the running greatly excited the dog, so that he took after Leon full howl. Leon could get away from the men, but the dog was a different matter and complicated the situation.

It seems that, although his father's library had been composed largely of religious books, Leon had managed to read a few novels in which hair-raising situations and narrow escapes were the ordinary affairs of the hero's life. So, when in his flight he came to a small river, he did just what the hero did in the stories—plunged in and waded a considerable distance around a turn and out of sight before climbing out on the other bank. The dog reached the water just as Leon left it and, baffled like the bloodhounds in the stories, howled a while and then gave up the chase. The boy concealed himself to rest from his flight. The voices of his pursuers came near, then moved away; and all was quiet.

While lying there in the woods, he realized that the clothes he had on were his only possessions and that they were not in good condition for going out into the world. He decided that he must go back home, obtain a change of clothes and make a new start. By tramping all day he reached the bank of the river about sunset at a point about two miles from home. There were no boats on that side, but by hunting about he found enough driftwood to make a raft and on this he poled across to his own bank. He again took to the woods for cover and at dusk arrived at the top of a hill very close to the house. His father, who must have searched a long time, arrived soon afterward and recounted the adventure to his mother.

Leon, thoroughly uncomfortable, remained in concealment until about midnight, at which time the lights had long since disappeared, and then he made his way to a shed from the roof of which he had often climbed into the chamber where he had been accustomed to sleep. He got into the chamber without arousing anyone and cautiously groped his way to his bed. There was no one in it. The situation was too much for his self-control. He was tired and cold and wet and hungry. He decided to get into bed and sleep but to waken before anyone else and go on his way.

* * *

What boy, outside of a storybook, could waken early under such conditions? It seemed that he had hardly lain down when he was aroused by the noise of the family below. He got out of bed at once, dressed in dry clothes, made a bundle of the still wet suit of the day before and was going toward a window from which he thought he could jump when his sister came into the room, saw him, screamed and ran downstairs. Leon found the window so high above ground that if he jumped he was likely to injure himself and hinder his escape. He ran back to the door which separated the attic from the stairs, shot the bolt and sat down to await events.

His father and mother evidently reached the bottom of the stairs at the same time. But here the mother's instinct was wiser than the father's reason, and Leon heard her say: "You go back and leave me alone with him." It is no small tribute to his father's intelligence that he did go back and that he accepted the arrangements which the mother and Leon made in their long talk. The old order of autocracy and temperamental severity was ended. Consideration and justice replaced them.

The father had had many hours of intense thought during the boy's absence. He must have realized that a New England farm was not well suited to satisfy the ambitions of growing boys and girls from a keen-minded and aggressive race. He probably saw that if they did not leave now they would as soon as their wings were strong enough and that then the home would be lost. Within two months he moved the family to Skowhegan, and two years later to North Vassalboro.

* * *

And thus a boyish escapade led to a complete change in the fortunes of all the family.

PART TWO

HISTOLOGICAL AND BACTERIOLOGICAL DISCOVERIES AND PRESENTATIONS

PREFACE TO PART TWO

When Dr. Williams began practice, science was almost a stranger to dentistry. Few dentists or physicians owned microscopes, and fewer used them. Even when they were used, the methods generally employed in preparing specimens of developing teeth often distorted or destroyed some of the more delicate structures, so that the most earnest student was likely to arrive at erroneous conclusions. Most dentists accepted the often repeated philosophical theories as to the development of teeth in the human embryo and the causes and processes of decay of human enamel and dentine.

Against these philosophical theories and those arising from incorrect technic an obscure dentist, working in a back room in a small town, largely with homemade apparatus, set his face and exercised his pen. Later, as a little-known stripling, he met the mightiest in the profession on the platform and in the press. He annihilated the philosophical methods of deduction in dental histology and bacteriology and wrote above their tomb, "Mene, mene, tekel, upharsin."

The labors thus begun have been diligently continued for more than half a century. They have made important contributions to our knowledge of the history of the tooth, from the beginning of the deposit of calcoglobulin to form the enamel until that enamel is destroyed by the formation of acid by the microorganisms of the bacterial plaque. Only a brief summary of the more important parts of the work can be given here.

CHAPTER IV

THE YOUNG DENTIST—HIS FIRST VISIT TO NEW YORK

THE drug store at North Vassalboro was kept by E. J. Roberts, D.D.S., who was both druggist and dentist for that locality. Part of the drug store equipment consisted of a circulating library, where were assembled many books. Leon soon learned about the library and became a subscriber so that he might take out books. It is said of him that his most frequent appearance on the village street was while returning a book or carrying home a new one.

Dr. Roberts soon noticed the stripling who was so interested in good books and asked him if he would not like to work in the store, where he could learn the drug business and also the practice of dentistry. Leon's family discussed the offer in a family council and advised its acceptance because Dr. Roberts stood well in the community as a man, a druggist and a dentist. And so, at the age of seventeen, Leon began clerking in the drug store. Forty years later Dr. Roberts told the writer of this book that he had always believed that Leon took the job to get a chance to read *all* those books rather than for the pay or the prospects.

LEON DECIDES TO BECOME A DENTIST

Leon soon decided that he would like to be a dentist and used all his spare time studying the textbooks of dentistry then standard: Gray's *Anatomy,* Harris's *Principles and Practice,* Dalton's *Physiology,* etc. He took a special course in chemistry under a professor from Colby University (now Colby College), located not far away. When Dr. Roberts saw the aptness and interest of his pupil in acquiring a dental education, he earnestly seconded the boy's efforts. He was a man of sterling qualities and unusual ability, thorough to the point of severity in requiring from his apprentice recitations which showed understanding of principles and accurate mechanical and operative work. At the end of two years he felt that Leon was qualified to enter practice. This enabled Dr. Roberts to carry out a plan which he had previously formed. He sold out the drug store and moved to the city of Augusta, where he continued the practice of dentistry until his retirement in May 1923 at the age of eighty-four.

Thus, in 1871, at the age of nineteen, James Leon Williams was launched into the practice of dentistry in the town of North Vassalboro, Maine. He had entered the profession through an apprenticeship, as had about half of the men then in practice. When the instructor was of the high mental type of Dr. Roberts and took an interest in the apprentice, the training compared favorably with that given by the dental colleges of the day. This method of study had the merit of being thoroughly practical because many of the theories could be immediately applied and their value ascertained. Williams was given the courtesy title of "Doctor," which he later was to make legal by passing the necessary college examinations and receiving his degree. He must have prospered in practice because a year later he married. His first wife was Alice P. Robinson, and of this union four children were born, of whom two sons survive. She died in 1881. In 1883 he married Estelle Whittier Lunt of New York, who died in London in 1908. In 1914 he married Lillian Sibbick of the Isle of Wight.

He Borrows a Microscope, Then Buys One

Soon after entering practice Dr. Williams was admitted to membership in the Maine Dental Society. He attended the meetings, where he found much to interest him. He learned that the Society owned a microscope which was loaned to the members in turn. Knowledge of microscopy was limited to a very few people in any branch of medicine. None of the physicians in or around North Vassalboro had a microscope. As there seemed to be little demand for this particular microscope, he was able to get it and keep it most of the time for two or three years. At the end of that period he had saved up his first hundred dollars. To the dismay of his friends, who thought him crazy, he invested it in a microscope that he might have one of his own.

In that day and location microscopy was carried on under difficulties and, of course, after the practice of the day was finished. He had to get such instructions in technic as he could from books and magazines, from the advertisements of microscope-makers and from correspondents. With many failures he mastered the technic of preparing material and making specimens. He had a room next to his laboratory, with one window facing south. For this window he made a cover with one small aperture to admit a single ray of light, hung a mirror outside in such way that it could be moved by pulling a string and would direct light through the aperture, and mastered the art of microphotography.

His histological studies convinced Dr. Williams that the theories then in vogue as to how the teeth are formed were incorrect. These theories were firmly entrenched in the minds of the leaders of the profession and were supported by prominent and forceful speakers. He contributed to the May 1882 issue of *The Dental Cosmos* an article entitled *Studies in the Histo-Genesis of the Teeth and Contiguous Parts.* It attracted much attention and aroused no little antagonism. He was to hear from those who approved his views and from those who opposed them in ways he little dreamed of then.

THE BEGINNINGS OF CROWN- AND BRIDGEWORK

On the morning of Sunday, June 18, 1882, the readers of the *New York Tribune* found, in a prominent location, a large display advertisement headed

THE RICHMOND TOOTH CROWN
OR ARTIFICIAL TEETH WITHOUT PLATES

Behind it was an interesting story. Dr. C. R. Richmond, while practicing in California, had devised the Richmond crown and had presented it to the profession in the usual way. Either then or later he appears to have devised the system of fixed bridgework which afterward came into such general use.[1]

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[1] A Dr. Low of Chicago disputed the priority of the use of dummies suspended to crowns.

He came to New York, stopping en route at some of the more important centers to give clinics before members of the profession. He was so profoundly convinced of the welcome the public would extend to the new work that he entered into an arrangement with Dr. L. T. Sheffield, secured extensive and attractive quarters in a fashionable residence section of New York, grouped about him a staff of dentists of recognized skill in special branches of dentistry and announced the opening of offices to the public by an extensive publicity campaign.

The response of the public was immediate, overwhelming and very profitable to Sheffield, Richmond & Sheffield. When one remembers that they promised artificial teeth without plates and considers the deplorable state of denture technic at that time, such response is not surprising.

THE REACTION OF THE DENTAL PROFESSION

The reaction of the public to this announcement was as nothing compared to the reaction of the dental profession. Something mildly approaching a state of frenzy supervened. It is said by some who lived through it that unless one had actually experienced its force, one could hardly conceive of its violence or the lengths to which it was carried. There were many reasons, some of them professional and more or less effective, others private and very urgent. The usual methods of professional presentation to the public had been ignored. In spite of the clinics which Dr. Richmond had given, most of the dentists of the city knew practically nothing about the new system; they could not make crowns or bridges for their patients and they had ready no explanations, no evasions, no excuses. Their more desirable patients, from a financial point of view, flocked to Sheffield, Richmond & Sheffield and received a kind and quality of service for which no condemnation was ready at hand.[1] The fees received by Sheffield, Richmond & Sheffield caused many a dentist to gnash his teeth. The whirlwind of rage which

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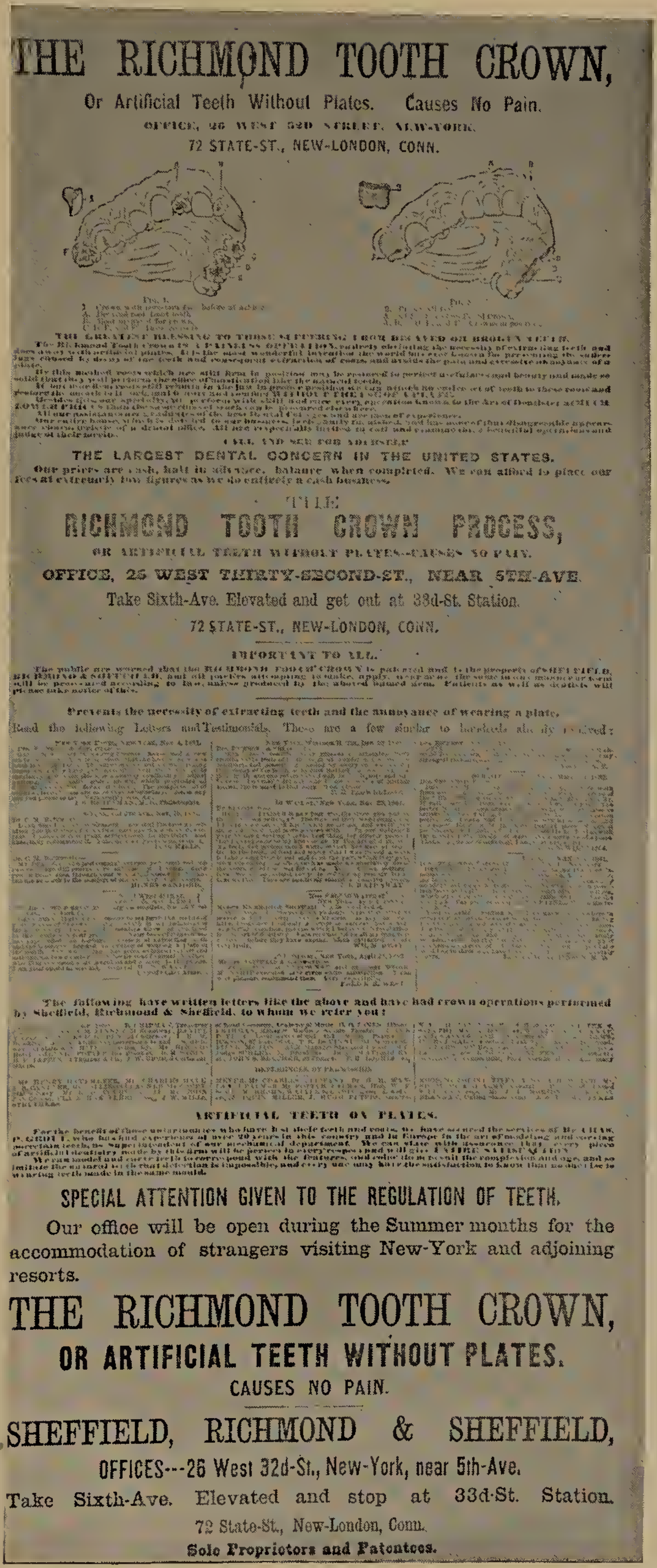
[1] The advertisement of June 18th gave, as references by permission, some of the most famous names in New York. They included Messrs. Henry and Charles Havemeyer, Louis Tiffany, Charles Tiffany, Daniel Frohman, Potter Palmer. The effect must have been tremendous in business and social circles.



THE RICHMOND TOOTH CROWN,

Or Artificial Teeth Without Plates. Causes No Pain.

OFFICE, 26 WEST 32D STREET, NEW-YORK.

72 STATE-ST., NEW-LONDON, CONN.

THE LARGEST DENTAL CONCERN IN THE UNITED STATES.

Our prices are cash, half in advance, balance when completed. We can afford to place our fees at extremely low figures as we do entirely a cash business.

THE

RICHMOND TOOTH CROWN PROCESS,

OR ARTIFICIAL TEETH WITHOUT PLATES--CAUSES NO PAIN.

OFFICE, 25 WEST THIRTY-SECOND-ST., NEAR 5TH-AVE.

Take Sixth-Ave. Elevated and get out at 33d-St. Station.

72 STATE-ST., NEW-LONDON, CONN.

IMPORTANT TO ALL.

Prevents the necessity of extracting teeth and the annoyance of wearing a plate.

Read the following Letters and Testimonials. These are a few similar to hundreds already received:

The following have written letters like the above and have had crown operations performed by Sheffield, Richmond & Sheffield, to whom we refer you:

ARTIFICIAL TEETH ON PLATES.

SPECIAL ATTENTION GIVEN TO THE REGULATION OF TEETH.

Our office will be open during the Summer months for the accommodation of strangers visiting New-York and adjoining resorts.

THE RICHMOND TOOTH CROWN,

OR ARTIFICIAL TEETH WITHOUT PLATES.

CAUSES NO PAIN.

SHEFFIELD, RICHMOND & SHEFFIELD,

OFFICES---25 West 32d-St., New-York, near 5th-Ave.

Take Sixth-Ave. Elevated and stop at 33d-St. Station.

72 State-St., New-London, Conn.

Sole Proprietors and Patentees.

Facsimile of Advertisement in *New York Tribune*, June 18, 1882.

Dr. Williams in Front of His London Office.

resulted was too great to permit discrimination. It involved the method of introducing the new work, the work itself, and everybody associated with it.

THE INVITATION TO DR. WILLIAMS

Among the dentists on the staff of Sheffield, Richmond & Sheffield was Dr. George Alden Mills, who had been a pupil of Dr. Riggs and was probably the leading pyorrhea specialist of the city at that time. He had been greatly interested in the paper by Dr. Williams which had been published in *The Dental Cosmos* the preceding May and, in the latter part of 1882, sent Dr. Williams an invitation to visit New York to read a paper before a dental club.

Violent as was the storm which raged in the profession of New York about Sheffield, Richmond & Sheffield, it had not disturbed the still waters of North Vassalboro, Maine. Dr. Williams had never heard of Sheffield, Richmond & Sheffield, or of bridgework, or of the furor which both had created. He supposed his invitation came from a group of reputable practitioners who had been interested by his presentation and who desired further light. So, in the fall of 1882, he visited the big city to read his paper.

Greatly to his surprise he found that the "dental club" was the staff of an advertising dental office, Sheffield, Richmond & Sheffield. His previous training had not prepared him for anything of this sort, and he took a little time for reflection as to what should be done. The more he sought light on his course, the more difficult it became to decide. With many of those whom he consulted, rage seemed to replace reason at the very mention of that office. Finally he decided to investigate for himself and spent two days in the offices of Sheffield, Richmond & Sheffield. He found a staff of unusually skillful operators, each a specialist in one line, with patients moving from one operator to another for different forms of service. Much of the work was mechanically fine. The office was thronged with patients, many of them among the socially and financially elect. They appeared to be well satisfied with the form of service they were receiving.

The Technic for Removing Pulps

It may be interesting to some of the younger men in the profession to learn about the technic employed in the office of Sheffield, Richmond & Sheffield to devitalize teeth which were to be used for the abutments of bridges. If a maxillary central was to be devitalized, a rather deep groove would be ground on the labial surface, close to the gum line and at right angles to the long axis of the tooth. A similar groove was ground on the lingual surface. The beaks of a pair of powerful cutting forceps were placed in the grooves and the crown easily cut off, of course exposing the portion of the pulp left in the root. An orange-wood stick which had been previously whittled to about the size and shape the operator expected the pulp chamber to be and immersed in carbolic acid was now placed on the exposed pulp and with a light blow of the mallet was driven into the pulp. With a broach that portion of the pulp was immediately extracted. Contrary to what might be expected, the operation is said to have been nearly painless in nine out of every ten cases. The grinding of the grooves usually hurt more than the removal of the pulp.

In the midst of this professional storm Dr. Williams was able to retain his powers of discrimination and to distinguish between the value of crown- and bridgework as a means of service and the method by which it had been introduced. He believed it to be capable of development into something of great value to the public. He returned to Maine, closed out his practice and joined the staff of Sheffield, Richmond & Sheffield about December 1882.

The Introduction of Staff Meetings

Sheffield, Richmond & Sheffield introduced some practices which, in somewhat different form, are reappearing in the dental profession. Meetings of the entire staff were held for the discussion of different problems in practice, and, when possible, dentists of known attainments appeared before them. One such meeting was held on a winter afternoon when a violent storm made it impossible for patients to reach the office. After the technical matters were disposed of, Dr. Sheffield began to talk about the prospects of development, which were then especially bright. Led on perhaps by the sound of his own voice, he rose easily from one level of vision to another and drew increasingly attractive pictures of the financial returns for the members of the staff. He had just remarked that he expected some day to see each member of the staff come to the office in a brougham, the most luxurious form of equipage at that time, when, chancing to catch sight through the driving snow of the Stewart mansion, the home of the widow of A. T. Stewart, one of New York's merchant princes, he added in a burst of enthusiasm, "And, gentlemen, I expect to see us housed in that palace yonder." There was absolute silence for a moment. Then the piping voice of Dr. Mills inquired, "Doctor, do you think you could get the old lady out on two weeks' notice?" Dr. Sheffield never mentioned that subject again.

The Call upon Dr. Atkinson

Soon after Dr. Williams entered the profession, he came into contact with the writings of Dr. W. H. Atkinson and formed a great admiration for him. It was natural enough, therefore, that on the occasion of his first visit to New York he should call upon Dr. Atkinson at his office and residence, 41 East Ninth Street. Dr. Atkinson answered his ring at the bell and invited him to enter. Williams introduced himself. Dr. Atkinson had a ready welcome for all the young men in the profession and immediately plunged into a series of questions to inform himself as to who Williams was and why he had come to New York. The answers must have been satisfactory because he went to the head of the stairs and called down to his son, Dr. Clinton Atkinson, "Clint, Clint, bring up a bottle of wine. There is a wise man from the East here!"

When Dr. Williams returned to New York and entered the offices of Sheffield, Richmond & Sheffield, the acquaintance with Dr. Atkinson deepened into a friendship which was a source of great joy to the younger man at least. Later, when Dr. Williams practiced in New Haven, he often spent the week-end with Dr. Atkinson. It was their custom to walk up Fifth Avenue on Sunday and observe the throng. Dr. Atkinson, who was a thoroughgoing aristocrat, would watch them for a long time in silence and then perhaps remark, "Look at them! Just look! Don't most of them look as if they were sorry they came!"

DR. WILLIAMS'S ESTIMATE OF DR. ATKINSON

Dr. W. H. Atkinson's life struck a high note. He inspired men to an increasingly fine perception of their possibilities and the subordination of any such consideration of self as would interfere with the discharge of their professional obligations. He was emotional and spiritual in character and had a power approaching genius for getting behind the mask of a man's words and deeds and testing the quality of his soul. If he found sincerity, unselfishness and progressiveness as the keynotes, he was a bubbling fountain of inspiration and help. If, on the other hand, he detected any inclination to prostitute professional standing to personal gain, his denunciation was prompt and unsparing and spoken without reference to its repercussion on himself. Once, in a professional debate, when he doubted the sincerity of his opponent, he said, "It has been one of the saddest experiences of a long life devoted to the interests of the profession and the service of humanity to see men deliberately turn their backs upon the source of light and gaze on their own shadows and say, 'My God, how dark it is!' " Naturally he was understood and loved by some and heartily disliked by others.

His high sense of spiritual values caused dentistry to be a part of his religion of service. So intensely did he concentrate upon his task of filling each day with his best efforts that he literally took no thought for the morrow. He kept open house for the members of his profession, who visited him in great numbers. And even in his later years, when the problem of mere sustenance was serious, he would order a bottle of champagne that he might properly entertain a visiting dentist, thrusting into the background the knowledge that it must be paid for by some privation of his own. He was so generous with money that, in spite of large earnings over a long period, he died poor.

In the hearts of those who loved him the memory of

W. H. Atkinson is like the sound of the sweet vesper bell at eventide, calling man to look up and not down and to be of good cheer because God is in His Heaven and all will eventually be right with the world.

CHAPTER V

The Debate with Garretson

WHILE employed by Sheffield, Richmond & Sheffield, Dr. Williams applied to the New York State Board of Registration for a license to practice in New York. He went to Albany, where the State Board was convened, taking with him a series of models he had made showing several cases of crown- and bridgework and also a patient exhibiting a full maxillary set in the form of a bridge. This work was critically examined by the members of the State Board and others. So novel was it, and so great was the general ignorance in the profession concerning it, that one prominent dentist asked the patient, "How could you sit in a dental chair long enough to have your teeth built up with gold in that way?" He thought the teeth had been built up with gold foil.

Dr. Williams was refused permission to appear for examination. The reason given was that Sheffield, Richmond & Sheffield were unprofessional and that association with them was an unprofessional act. This antagonism was largely official. Privately the leading members of the profession showed an intense interest in the work and a desire to master its principles.

The Visit by Dr. Gaylord

About the time that Dr. Williams felt that he had pretty well mastered the principles of crown- and bridgework, as they were then known, there visited the offices of Sheffield, Richmond & Sheffield a dentist who, like himself, was big enough to distinguish between the methods by which the work had been introduced and the possible merits of crown- and bridgework as a form of dental service. He was Dr. E. S. Gaylord of New Haven, Conn. He had heard a great deal about the work, and Dr. Richmond had operated on one or two of his patients.

He became acquainted with Dr. Williams. Something in each must have attracted the other because he invited Dr. Williams to become associated with him in New Haven. In the spring of 1883 Dr. Williams accepted, and thus began a friendship which has continued to this day. Dr. Gaylord and he held the same ideals for the development of the profession and were contentedly industrious in transmitting them into practice.

THE FIRST PROFESSIONAL ARTICLES ABOUT BRIDGEWORK

While associated with Dr. Gaylord, Dr. Williams prepared two articles under the title, *A Consideration of the Merits and Claims of Artificial Crown- and Bridgework.* The first of these articles was published in *The Dental Cosmos* of December 1883. These were the first articles presenting a comprehensive view of the principles and practice of crown- and bridgework ever published in a professional journal. At this time also, by extra study, he passed the examinations of the Baltimore College of Dental Surgery and received the degree of D.D.S.

GARRETSON AND CRYER AS HISTOLOGISTS

Meanwhile, Dr. Williams's writings on dental histology had attracted a good deal of attention in the dental profession and aroused no small amount of opposition on the part of those who held different views, including two men of great ability, high standing and fighting courage. The more prominent was Professor James E. Garretson, generally recognized at the time as the greatest oral surgeon in the dental profession and also a leading teacher. His assistant in surgery was Dr. Matthew H. Cryer, who was later to become even more famous as an oral surgeon than his chief. He admired Garretson, believed in him, dearly loved a good fight and joined him with right good-will in an effort to defeat Williams and his histological theories publicly.

Garretson made no secret of his scorn for a microscope, but he was far too shrewd to overlook any procedure which might make his victory certain and complete. So he sent to a certain Mr. Cole in London, England, whom he regarded as the world's leading dealer in microscopic specimens, for the best specimens of developing teeth that he could prepare. He and Cryer studied the specimens and saw in them what they believed confirmed the Goodsir theory of tooth formation, which Garretson supported.

Garretson Seeks to Annihilate Williams

The opportunity to annihilate Williams in full view of the profession occurred at a union meeting of the Connecticut Valley Dental Society with the New England Dental Society at Providence, R. I., in 1883. Dr. Williams was to speak in the evening on the development of teeth as he had studied it through the microscope. Professor Garretson was on the program to speak in the afternoon, but the title of his paper was not given. When Dr. Williams arrived in Providence, he learned that Professor Garretson and he were to speak on the same subject, Garretson preceding. Garretson's antagonism to Williams's theories was well known in Pennsylvania, New York and southern New England, and the opening of the afternoon session found the auditorium packed with an audience of representative dentists.

Professor Garretson had the courage of his convictions. This was to be a battle to the death between mutually destructive theories. He proposed to give no quarter and asked none. Fortified by his study of the slides he had received from London, he announced in ringing terms that he intended to take a position from which no retreat was possible. He then stated his main theme: that a sound philosophical theory of tooth development would teach one far more than could be learned by looking through a microscope. This theory was metaphysical in character. It held that the design of every part of an organ is complete in the germ of that organ and that development is effected by the expansion of the minute organ in the germ to the big organ of service. It is the old and famous theory of preformation. One learned how the theory worked, in the development of a tooth, by keeping in mind the form of the completed tooth and thinking out, quietly and without the use of evidence, what nature must have done to produce that tooth.

THE CURRENT CONCEPTION OF TOOTH DEVELOPMENT

Professor Garretson had long before accepted the Goodsir theory of tooth formation then current that the teeth are formed in an open groove in each jaw, the crowns growing upward from the bottom of the groove and the roots growing from the bottom of the groove down into the underlying tissues. His more detailed conclusions, as summarized and quoted from *The New England Journal of Dentistry* of 1883, were that the "dentine, cementum and enamel are resultant of a common secretion, and this secretion lies with the dental pulp. There is no enamel pulp as propounded . . . by the microscopist."

"A germ (tooth germ), originally microscopic, has enlarged until it stands in shape and size the representative of a tooth."

"The formation of dentine completed, the covering of it with enamel begins. . . . Secreted by the same pulp which forms the dentine, the same secretion, some portion finds its way into and through the primary sac. As it passes through this sac to be moulded against the second, it is modified by the epithelial surface, which constitutes the outer face of the tunica propria. . . . Between the enamel thus formed and the dentine exists the primary sac, simply the modified mucous membrane, which we first saw as overlying the papilla. The sac of mucous membrane continues to exist between these two hard bodies, and receives and modifies, for the support of the enamel, the liquor sanguinis found in the dentinal tubules and intertubular substance."

"It is also understood that it (enamel) calcifies from the outside inward, and *not* from the inside outward."

Probably because of his scorn for the microscope Garretson did not show any illustrations, though he told the story of the specimens received from London and their confirmation of his theory. He then delivered an impassioned attack on the theories he knew that Williams held. Williams's face must have shown something of his concern, because at the end of Garretson's speech Dr. Thomas Fillebrown of Boston, presiding officer, came to where Williams was sitting and whispered, "Buck up now! Fix him!"

WILLIAMS REPLIES TO GARRETSON

The evening's session found the auditorium thronged to its utmost capacity. The young and little-known stripling was to repel the terrific drive of the afternoon or go down before it. Principles and theories were at stake. Dr. Williams prepared his way by a few references to Professor Garretson's sureness in his position and led up to a quotation from Mrs. Browning's *Aurora Leigh,* in which she refers to what her father had taught her. She says:

> Out of books he taught me all the ignorance of men,
> And how God laughs in heaven when any man
> Says: "Here I'm learned; *this* I understand;
> In *that* I am never caught at fault or doubt."

The audience caught the sense of the reference at once, and from that moment a considerable portion of its sympathies was with the younger man.

The concern in Williams's face which caused Fillebrown to urge him to "buck up" was not the result of fear, for he knew from what Garretson had said that Garretson was delivered into his hand. He knew just why Garretson thought the teeth developed in an open groove, why he thought there was no special organ for the formation of the enamel, and why he believed that the dentine, cementum and enamel were all formed from a single secretion prepared by the dental pulp. And he knew that he not only could disprove every important statement Garretson had made, but could establish beyond question that more could be learned by correct use of a microscope than by going back into a corner and sitting down and thinking how nature ought to have done it.

CORRECT AND INCORRECT TECHNIC

It all went back to an imperfect technic in common use at the time in the preparation of microscopic specimens and employed by Cole in preparing the specimens for Garretson and Cryer. Those specimens were mounted in balsam. The stellate reticulum of the enamel organ is an exceedingly delicate structure. It has never been possible to preserve it or represent it properly in balsam-mounted specimens, because the shrinkage caused by that method greatly distorts it or completely destroys it and it is washed out during the chemical treatment necessary to the preparation of the specimen, leaving an empty space where it is of the greatest importance that this tissue should be shown. The space made by the destruction of the stellate reticulum misled Garretson and Cryer into the belief that it was filled with secretion from the pulp which would eventually form the enamel, dentine and cementum.

Dr. Williams had been compelled to learn the art of preparing specimens from such publications and advertisements of apparatus as he could get while still in Maine. His difficulties had brought him into correspondence with Dr. Lionel Beal, at that time one of the great authorities on histology in England, whose work had attracted world-wide attention. In his letters to Dr. Williams, Dr. Beal had suggested that for many histological purposes, such as immediate study and photography, glycerine was a far better medium for mounting specimens than balsam because it caused practically no shrinkage or destruction and left the tissue in a more nearly normal condition than any other method that had been discovered. Dr. Beal was the originator of this method.

Williams had made many specimens by the balsam method and had seen just what Garretson described. His dissatisfaction with what he saw and his belief that it did not represent the facts led to his correspondence with Beal. And he had made many specimens by the glycerine method. He felt sure that they were correct and told an entirely different story.

He first showed pictures of slides made by the balsam method and called attention to the open spaces which Garretson had described, one forming the open groove, the other supposedly filled with secretion by the dental pulp. He then showed pictures of sections made by the glycerine method and explained how the outermost layers of the epithelium over the tooth bud and the stellate reticulum and ameloblasts within the enlarged end of the tooth bud are destroyed and washed away by the balsam technic. He followed with a long list of pictures showing teeth in all stages of development and the relations and functions of the tissues concerned.

Garretson had emphasized the statement that the enamel is formed from without inward and *not* from within outward, and that the enamel, dentine and cementum are formed from a secretion arising in the dental pulp. Dr. Williams showed that enamel is formed from its own organ, that it is deposited from within outward, that the dentine and cementum have their own proper forming organs and that the dentine alone is formed from the so-called dental pulp.

There was no discussion of Williams's paper. He was immediately elected an honorary member of the New England Society by an enthusiastic audience. Evidently he had "bucked up"!

* * *

How characteristic was this scene of more than forty years ago—the nearly unknown youngster, strong in his belief in scientific philosophy! How prophetic was the outcome! Within a relatively short time Professor Garretson established a chair in microscopy in his own college and appointed to it Dr. W. X. Sudduth, a firm supporter of Dr. Williams's theories.

CHAPTER VI

The Debate with Heitzmann

WHEN Dr. Williams had been in New Haven about a year, he contracted malaria. The climate there is sometimes severe, and this made it difficult for him to regain his strength. His physicians advised him to move to a milder and more even climate. In spite of this advice he remained in New Haven as long as his physical condition made it at all possible because he was so loath to break the happy association with Dr. Gaylord. His removal, however, did not break the friendship, which has always remained as one of his sentimental treasures.

Dr. Williams Moves to Philadelphia

At the suggestion of Dr. J. W. White, the veteran editor of *The Dental Cosmos,* Philadelphia was selected as a place of residence, partly because the climate in winter is usually mild and open and partly because he had been offered the post of Professor of Physiology and Histology in one of the leading dental colleges. His health made it inadvisable for him to undergo the close confinement necessary to the discharge of professorial duties, but he moved to the city and entered practice.

Hardly had he settled there when there came to the surface an echo of the agitation about crown- and bridgework which showed the difference between the official attitude toward it and the real, under-the-surface attitude. A professor of national reputation in a prominent dental college borrowed all of Dr. Williams's lantern-slides and models, together with his writings, and delivered a lecture to his class as if all this material were of his own production.

While Dr. Williams was located in Philadelphia, there occurred an amusing reminiscence of his meeting with Professor Garretson in Providence in 1883. A well-known dental teacher invited him to attend a clinic by Professor Garretson. The operation was the removal of a large part of the superior maxilla and malar bones on one side, and the patient, already anesthetized, was just being laid on the operating table, beside which Professor Garretson stood, when Dr. Williams and his friend entered the crowded amphitheatre. They quietly dropped into seats, but not before Garretson's sharp eye had caught sight of them, and he instantly shouted out, "Ah, Dr. Williams, is that you? Well, I am cock of the walk here anyhow." "And," says Dr. Williams, in relating the circumstance, "he *was* 'cock of the walk' truly, for I never saw a more brilliant piece of oral surgery than he performed that day. In surgery he was master of the situation, while in histology he was not; and that made all the difference."

JOHN W. KEELEY AND HIS MOTOR

It was thought that the inroads which had been made on Dr. Williams's health by the confinement in the dental office and the extra hours spent in microscopy and scientific study might be partly overcome if he could be much in the open air and have some avocation less serious and confining than his regular study. So he undertook to prepare for *The Century Magazine* an article on John Worrel Keeley and his motor, a subject in which he had been much interested.

Keeley has gone and is now largely forgotten, but thirty-five years ago he was the subject of endless discussion. He claimed to have discovered a new form of physical force which he could employ for many purposes, and he was seeking to capitalize companies for marketing it. He may have been a charlatan, but he had all the wise ones guessing. One of the standing questions in many a daily paper was, "What Makes the Keeley Motor Mote?" Dr. Williams visited Keeley's laboratory many times, sometimes alone, sometimes with distinguished scientists. For hours at a time they witnessed the most astounding demonstrations which they could not in the least understand. Everything seemed ready for the article, which, in that magazine, would give Keeley enhanced standing, when a new test occurred to Dr. Williams. Going straight to the laboratory, he said to Keeley, "You have often remarked that the force with which you charge the cylinders is generated in a few seconds." "Yes," replied Keeley, "that is correct." "Well," said Williams, "I should like to see the cylinders charged and discharged into the air of the room two or three times." Keeley had always been most cordial and accommodating, but upon hearing that request he gave Williams a long black look and went into another room and closed the door. Dr. Williams never saw him again.

Keeley did, however, anticipate LeBon and others by more than fifteen years in the formation of certain scientific terms, such as "interatomic force," which are now commonly used in describing new conceptions of force.

THE HEITZMANN SCHOOL OF HISTOLOGY

While Dr. Williams was located in Philadelphia, there occurred another histological battle royal. Dr. W. H. Atkinson never joined in the whirlwind of denunciation of Sheffield, Richmond & Sheffield, and his friendship for Dr. Williams was not in the least affected by Williams's association with them. There was in New York at this time a school of histology conducted by Professor Carl Heitzmann. Dr. Atkinson regarded the instruction given by this school as the best to be had and sponsored the school, in a way, to the dental profession. At Atkinson's urgent solicitation Dr. Williams became a pupil. He had as fellow-pupils Dr. C. F. W. Bodecker, who later went to Germany, and Dr. Frank Abbott, Dean of the New York College of Dentistry.

The study in Heitzmann's school was a course in practical dental histology conducted by means of microscopic work and verbal instruction from Professor Heitzmann. A very important part of the course was to require students to make drawings of what they saw in the microscopic specimens. While certain portions of the instruction met with Dr. Williams's approval, he soon formed the opinion that it was governed by two theories which Professor Heitzmann had previously formed and that pupils were influenced to see in the specimens whatever supported these theories and to minimize whatever opposed them.

THE RETICULUM THEORY OF HEITZMANN

The first of the two theories to which Professor Heitzmann was committed was known as the "Reticulum Theory." It is difficult now to state this theory in a way which would have been satisfactory to the sponsors for it, since most of them are dead and gone and it has long since been discredited. In general terms, the theory held that the cells of the body are joined to one another in a framework or reticulum which makes the body one homogeneous structure from top to toe and that the specialized tissues of the body are held in this framework. This idea will be readily understood by one who has seen the towering steel framework of a modern skyscraper and afterward has watched workmen fill in the concrete for floors and walls. The steel framework might be said to represent the reticulum. Dr. G. V. Black called it the "theory of protoplasmic strings" and said it made Heitzmann want to picture wire screens all over his histological drawings.

This theory not only described the arrangement of the tissues in the grosser structures of the body, but also governed the arrangement of materials within the cells, including the nuclear material, and limited the activities possible within the cells to those which were permitted by the reticular arrangement. Believers in this theory rejected, firmly and without hesitation, all the presentations of the first discoveries regarding mitosis (cell division) and attributed the changes which others saw, as precedent to cell division, to effects produced during the preparation and staining of specimens.

THE MEDULLARY THEORY OF HEITZMANN

The second theory, which was known as the "Medullary Theory," held that all the specialized tissues of the body are developed from one particular form of tissue found in the embryo, known as "medullary tissue" or "medullary corpuscles," the constituent tissue of the original reticulum. When a tissue which had already become specialized, and which was thereby partly qualified for its work, changed its function to complete the work (as when the columnar epithelium of the tooth bud becomes the enamel rod by depositing the salts of the calcoglobulin), that tissue could not change directly and by the simplest route from columnar epithelium to enamel rod, but, by this theory, was compelled first to return to the condition in which it originated (medullary corpuscles) and from there effect the new specialization. This is as if a runner who has been given a handicap in a race and is already part way to his goal were compelled to make his race by first running back to scratch and thence to the goal.

Dr. Williams well knew the menace of dominance over the mind by preconceived theories in general and by these in particular. He resigned from the school and for about two years spent all the time that could be spared from practice in preparation to refute both the Reticulum and the Medullary Theories. The wisdom of his decision is shown by the fact that continued dominance by these theories would have closed the door against all the progress which has been made in the knowledge of the phenomena attending cell division and against the significance of the chromation of the cell in all that has been learned about heredity during the last thirty years. And that means about all that is known today in this very important field.

THE FIRST PUBLIC CONTROVERSY WITH HEITZMANN

The opportunity for the presentation of what Dr. Williams believed to be better theories of certain phases of tooth development occurred at the seventeenth anniversary meeting of the First District Dental Society, New York, December 9, 1885. . Even now, forty years afterward, the story, as told in *The Dental Cosmos* for 1886[1], indicates that it must have been a "dandy scrap." He did not mention the Reticulum Theory, as such, at this meeting, but it underlay, in part, all that was said.

Dr. Williams opened the attack with a paper entitled *A Critical Essay on the Development and Minute Anatomy of the Teeth in Health and Disease*[2]. He unqualifiedly contradicted the following theories held by Professor Heitzmann and taught to his pupils: that a reticulum exists and extends throughout the body; that specialized tissues return to the condition of medullary tissue and respecialize from there; that distinct organic fibers are found in enamel (probably as part of the reticulum); that the dentine is histologically identical with bone; and that decay of the dentine is an inflammatory process.

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[1] The story is told in several articles in *The Dental Cosmos* for 1886, beginning on pages 65, 257, 304, 306 and 377.

[2] *The Dental Cosmos*, 1886, page 65.

The fun of the meeting really began when Professor Heitzmann was called upon to open the discussion, following a paper by Dr. Sudduth. He ignored Sudduth and immediately undertook to demolish the upstart who had dared to question the theories which he had formed as the result of twenty-five years of study. Certainly the audience at that meeting had no reason to complain of dullness.

Professor Heitzmann was a very intelligent man, a powerful speaker and a skillful debater. He knew well how to take with him those persons in his audience who were not fully informed and could not closely follow the technic of what was said or shown. He must have known why Dr. Williams left his school after so short a term and doubtless welcomed this opportunity to settle what he felt to be a score between them.

He opened his discussion with the story of a young farmer who reached the age of twenty-five before he learned the alphabet. As he mastered letter after letter, his enthusiasm grew. When he got as far as the letter *k*, he could not wait to learn more, but started out to teach what he had learned. By this story he sought to put Williams, who had remained in his school too short a time to complete the alphabet, in the place of the half-prepared young man who, with inadequate training, presumed to teach.

Some of Heitzmann's assertions make interesting reading now. They show how unwise it may be for even a supposed master to assert his opinions too dogmatically, lest the knowledge gained tomorrow discredit him. A few of them were:

"I had supposed there was not the least doubt that the dentine is globular in its structure, the same as bone."

"I have come to the conclusion that the odontoblasts cannot be direct dentine-formers."

"The odontoblasts are not permanent, stable forms. As soon as the dentine is about to form, the odontoblasts break down or split up into medullary corpuscles. The odontoblasts are not direct formers of dentine but the medullary corpuscles are."

Professor Heitzmann then directed some hot shot at Dr. Williams's theories of enamel formation. He began by saying that Dr. Williams's histology was yellowish with age, a little musty. With that as a starting point he dealt with the presence of organic fibers in the enamel, quoting Professors Wedl and Tomes, and expressed the fear that Williams's viewpoint was at least ten years behind the times. He affirmed his belief that epithelial tissue changed to connective tissue and vice versa, told another funny story, accused the ameloblasts of a sort of hide-and-seek, in-and-out dance with medullary corpuscles, while forming enamel rods, and closed with a strong presentation of the decay of dentine as an inflammatory process.

DR. BLACK SUPPORTS DR. WILLIAMS

One of the interesting features of the record of the meeting is the manner in which the president, Dr. W. W. Carr, introduced Dr. G. V. Black as "Professor Black of Jacksonville, Illinois." Dr. Black reviewed briefly the controversy over the character of decay of the dentine, beginning with the writings of William Robertson of Birmingham, England, in 1835, followed by Regnard, Desirabode, Hunter, Fox, Tomes and Magitot, and showed that the advance of knowledge since Robertson wrote had made it possible to find lactic acid and the organism which produces it. The action of the acid in producing decay *independently of the vitality of dentine* was also well established. This answered Heitzmann's theory that decay of the dentine is an inflammatory process.

He then discussed the theory that one specialized tissue changed into another, via the medullary corpuscles, and said: "There is a certain impress made in the fertilization of the ovum or seed that preordains just how far this differentiation shall go. Epithelium remains epithelium . . . but never becomes connective tissue. The connective tissues . . . never under any circumstances form epithelial tissue."

At this point Dr. Black took time enough to refer to the pictures which Professor Heitzmann had drawn on the blackboard and the funny stories he had told about a couple of farmer boys, in the following words: "We have heard during this discussion the parable of John and Bob. These boys are at it in earnest and they are after the old man, my friend here (Professor Heitzmann), and unless he gets his foot out of that rut (pointing to the illustration Heitzmann had drawn of the enamel organ), the boys will catch him and use him up completely." (Dr. Williams did that some years later, but that is another story.)

Dr. Black paid his respects to the Reticulum Theory in a very interesting series of illustrations. It will be sufficient to quote his closing words. "No matter what claims may be made as to seeing this reticulum connecting the cells, the interpretation placed upon it is wrong and all theories based upon it topple and fall to the ground."

During Dr. Black's discussion he was interrupted by voices from the audience, and one who reads the account cannot help feeling that twenty-five years later, when "Professor Black of Jacksonville, Illinois," would probably have been introduced simply as "Dr. G. V. Black," none of the men would have dared to interrupt him in that or any other way.

Quite a sharp tilt occurred between Drs. Williams and Heitzmann during the close of this discussion. Williams countered on Heitzmann's stories by the quotation from Josh Billings, "It is better not to know so much than to know so many things that ain't so."

This discussion cleared the air somewhat for those listeners who were histologically well informed. For the others the result seemed inconclusive, and Heitzmann's force and wit left the honors about even. Its greatest value was to help set the stage for another contest in which Dr. Williams effectually disposed of the Reticulum Theory, the Medullary Theory and the Inflammation Theory of decay of the teeth.

CHAPTER VII

THE ESTABLISHMENT OF PRACTICE IN ENGLAND

IN SPITE of every effort to regain his health Dr. Williams grew steadily worse until his voice was so far gone that he could not speak above a whisper. He had had recurrent attacks of bronchitis and it was believed that he was developing tuberculosis. When the physicians advised a change of climate, he decided to go to a sanitarium in the Alps and sailed from New York in March 1887.

DR. WILLIAMS VISITS LONDON

It is natural, on the occasion of a trip to Europe, especially the first, that the thoughts of every scion of the English race should turn toward England and particularly toward London. Much that made his history possible happened there. Even if the people who made the history have long since turned to dust, many of the places remain. If he visits them understandingly and has the power to shut the present out of mind, at least for a little, he can revivify, in part, the occurrences and understand better who these people were and what they did and why. They and their deeds become a little more a part of his life. Dr. Williams found London a source of delight and stayed longer than he had intended. Soon he noticed that his voice was returning and he was improving, so he decided to remain as long as the improvement continued.

He had been in London only a short time when he received a note from a Mrs. Bloomfield Moore, a wealthy American lady who lived at Mayfair and was prominent in the English literary world. She was very much interested in Mr. Keeley. As she had learned that Dr. Williams was exceptionally well informed upon the subject of Keeley's achievements, she invited him to meet a group of her friends at her house to tell them what he knew, and he accepted the invitation.

Dr. Williams Meets Browning

On arrival at the house Dr. Williams was introduced to a group of eight or ten representative Englishmen, most of them occupying important positions in the army or navy or associated with substantial scientific institutions. One of the last arrivals had all the appearance of a business man of large affairs. Mrs. Moore introduced him as Robert Browning, the poet.

Dr. Williams explained that Mr. Keeley claimed to have discovered a new form of physical force which tore the molecular or atomic structure of the air apart somewhat as heat forces apart the molecules of water. He claimed that this force was produced by musical vibrations in the elaborate machine he had invented. In one of his demonstrations he showed a small motor which was caused to run by playing *Home, Sweet Home* on a mouth harmonica. Keeley claimed that this motor was attuned to the keynote of that music and that it would not run when any other music was played. In the experiment as conducted by Keeley this proved to be true. When Dr. Williams reached this part of his explanation, Mr. Browning interrupted by asking a question. Mrs. Moore, who was an enthusiastic believer in Keeley, did not wait for Dr. Williams to answer the question, but started off on a long talk regarding the fundamental principle of Keeley's invention. Mr. Browning sat quite still until she had finished and then quietly remarked, "I will now show you exactly what I wished to know," and went over to the piano and began to play *Home, Sweet Home,* with his own improvisations, changing the key several times.

Browning was an expert musician and he became so absorbed in what he was doing that he lost all consciousness of the occasion and went on playing for about fifteen minutes. Suddenly he came to himself and jumped up, saying, "This is what I wanted to know, whether the machine would run on the keynote or on any note of *Home, Sweet Home,* if the key were changed." The unconscious humor of the situation was evident to all, but no one would have thought of interrupting the poet while he was playing or would have required him to propound a more exacting question to meet the amenities of the situation.

Dr. Williams's London Garden.

ENTERS PRACTICE IN LONDON

Under the influence of the English climate Dr. Williams continued to improve in health. He decided to remain in London, at least for a time, and sent for his wife. There he entered practice by forming a partnership with a prominent Harley Street dentist. For the benefit of those who are not familiar with London it should be said that Harley Street was for many years the most aristocratic professional street in the world.

Dr. Williams formed and has always retained a high opinion of the scientific acquirements of the English dentists, but found that not so much attention had been given to the mechanical aspect of operative dentistry and some forms of prosthetic dentistry as in America. In the making of artificial dentures on gold bases, however, the English dentists were far ahead of the Americans. Crown- and bridgework were practically unknown in London, and this offered an excellent opportunity for him to carry to his English confrères what was probably the first practical knowledge of the subjects ever put before them.

Dr. Williams decided to apply for the English degree of L.D.S. and in all professional and scientific matters to ally himself with the English dentists. He therefore took the examinations at the Royal College of Dentistry, Ireland, and made several trips to Dublin for that purpose. On receiving his degree he entered practice for himself. His attainments soon attracted a desirable clientele and he practiced continuously in London for twenty years, save for a number of periods of relaxation necessitated by ill health. During his holidays he undertook expeditions to famous localities in England and on the Continent. Parts of four summers were spent about Stratford-on-Avon. Here he rambled, meditated and photographed. The results were embodied in a beautiful volume published by Scribner's. The stories of these literary rambles are too interesting to be omitted, yet too long to be told here; but they are briefly recorded in Part Five of this book.

CHAPTER VIII

EVENTS LEADING TO THE PRESENTATIONS IN HISTOLOGY AND BACTERIOLOGY

IN 1894 Mr. Ash, head of Claudius Ash & Sons Company, handed Dr. Williams a copy of a book entitled *The Anatomy and Pathology of the Teeth* by C. F. W. Bodecker, D.D.S., M.D.S., and asked him to write a review for *Ash's Quarterly.*

There were special reasons why Dr. Williams should be interested in this book. Williams and Bodecker had been fellow-pupils in Heitzmann's school of histology, but Bodecker had accepted Heitzmann's theories and remained a more or less frequent attendant at the school for many years. Bodecker had also taken part in the meeting before the First District Dental Society (New York) in December 1885, supporting the views of Heitzmann that living fibers are present in the enamel and that decay of dentine is an inflammatory process. The discussion in New York had not been conclusive in the sense that the contestants on either side had considered their theories beaten and had retired from the field. This book was, in fact, a presentation in print of the theories which had formed the subject of discussion at the New York meeting.

DR. BODECKER CHALLENGES THE CELL THEORY

Dr. Williams read the book carefully twice. He found in the preface this statement: "So long as the cell theory holds sway over the minds of the majority of microscopists, the views here laid down cannot meet with general acceptance. As early as 1859 no less a man than Thomas H. Huxley declared that the history of the development of the teeth was not intelligible upon the grounds of the cell theory. . . . How long it will be before the novel views advanced by Dr. Carl Heitzmann, and which are directly antagonistic to the cell theory, will gain a final victory it is impossible to foretell." Dr. Bodecker then acknowledged his indebtedness to Professor Heitzmann for the illustrations and for aid in microscopical researches.

* * *

Most of us have no adequate idea of the struggle by which the blessings and opportunities we enjoy have been made possible. We are born or graduated to a certain condition brought to pass only by self-denial, molelike patience in digging for knowledge where light has not yet penetrated and courage to fight for convictions on the part of many of whom we know too little. The cell theory is now dominant in all histology; but when Bodecker's book was issued, it was by no means dominant in dental histology. The fact that this book bears on the title page the words

"Adopted by the National Association of Dental Faculties
as a Text-Book for Dental Students"

shows that the Heitzmann-Bodecker theories were credited by those then in control of dental education.

CELL THEORY VS. RETICULUM

It is worth while to pause long enough to summarize Bodecker's theories by excerpts from his book. He first briefly reviewed the cell theory. Schleiden (1837) and Schwann (1839) considered that "vegetable and animal organisms were composed of cells and their derivations, viz., intercellular substance. The cell was considered to be an individual, and composed of a vesicle with liquid or semi-liquid contents, and a central nucleus. An organism, it was thought, was built up of millions of such cells." Virchow (1852) stated that the cell was the seat of life and held that the organism was composed of a large number of individual cells, separated from one another by an intercellular substance which he considered to be the product of secretion on the part of the cell.[1]

In 1873 Dr. Carl Heitzmann, at that time in Vienna, exploited the theory that a cell, hitherto considered structureless, possessed a pronounced reticulum. He called the substance which builds up the reticulum the "living matter proper." "Not only do all movements occur in consequence of contraction and extension of the reticulum, but all new formations and outgrowths start from this substance, respectively from the granules, the points of intersection of the reticulum. This again proves that the reticulum is the living matter proper, in the meshes of which there exists a liquid holding nitrogen, but, being a liquid, not endowed with the properties of life."[1] Heitzmann later discovered that the intercellular substance is alive in the same sense as the cells themselves and that the reticulum is present in this substance also but is rendered invisible by chemical changes and a solidification of the originally liquid contents in the meshes of the protoplasm.

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[1] *The Anatomy and Pathology of the Teeth,* Bodecker, pages 58 and 59.

In addition to this theory of the reticulum Bodecker accepted the Medullary Theory, which has already been sufficiently well described for the purposes of this book on Page 46.

Decay as an Inflammatory Process

The third theory in Dr. Bodecker's book to which Dr. Williams took exception was that decay of the dentine is an inflammatory process similar to that in bone. A fair conception of this theory can be formed by assembling excerpts from the papers given at the meeting in New York in 1885 and from Bodecker's book.

"It is a well-known fact that dentine becomes the seat of an inflammatory reaction by caries. . . . There occurs a primary inflammation in dentine, independent of pulpitis or pericementitis, running its course in the middle of the dentinal tissue and leading, as all inflammatory processes do, either to a new formation or to destruction by suppuration."[2] The book says that the cause is unknown in some cases and that in other cases pericementitis or pulpitis may have been the cause. In all cases an incomplete calcification of the dentine and intercellular substance was observed. Traumatism and irritation were much more frequent causes.

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[1] *The Anatomy and Pathology of the Teeth,* Bodecker, page 63.
[2] *The Anatomy and Pathology of the Teeth,* Bodecker, page 370.

In predicating a structure which permits inflammation of the dentine the book calls attention to the similarity between bone and dentine and the fact that (according to this theory) the intercellular substance in both tissues is traversed by a large amount of living matter in the form of the reticulum. "Inflammation causes a solution of the lime salts and afterward a liquefaction of the basis-substance, both in bone and dentinal tissue.[1] . . . Eburnitis (the name which Bodecker gave to primary inflammation of the dentine) begins in the middle of the dentine, without any direct connection with the outer surface or the pulp cavity of the tooth."[2]

ABBOTT'S STATEMENT OF THE THEORY

This theory had been more forcibly stated by Dr. Frank Abbott during the anniversary meeting of the First District Dental Society in 1885, as follows:

"The first lesion in the carious process of human teeth is a solution of the lime salts of the surface of the enamel by some acid. . . . As soon as the living matter is reached it becomes irritated, which irritation if allowed to proceed soon assumes the condition of inflammation of that tissue and advances along the enamel fibers *in advance* of the solution of the lime salts by acids. When it reaches the dentine this inflammatory condition advances more rapidly, and is much more intense, in consequence of the greater amount of living matter to become affected. The lime salts, after having been *dislodged by the swelling of the living matter,* are dissolved by acids and washed away. As they are carried away the reticulum of the former odontoblasts again presents itself and is eventually destroyed by putrefaction. During the latter process this portion of the decaying tooth becomes filled with 'organisms of decomposition.' "[3]

Dr. Bodecker quotes both Dr. Abbott and Dr. W. D. Miller on the theories of decay of the teeth. Dr. Abbott's conclusions, in part, are as follows:

"Caries of a living tooth, therefore, is an inflammatory process, which, beginning as a chemical process, in turn reduces the tissues of the tooth into embryonic or medullary elements, evidently the same as during the development of the tooth have shared in its formation; and its development and intensity are in direct proportion to the amount of living matter which they contain, as compared with other tissues.

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[1] *The Anatomy and Pathology of the Teeth,* Bodecker, page 373.
[2] *The Anatomy and Pathology of the Teeth,* Bodecker, page 374.
[3] *The Dental Cosmos,* 1886, pages 318, 319.

"The medullary elements, owing to want of nutrition and to continuous irritation, become necrosed, and the seat of a lively new growth of organisms common to all decomposing organic material.

"Micrococci and leptothrix by no means produce caries; they do not penetrate the cavities in the basis-substance of the tissues of the tooth, but appear only as secondary formations, owing to the decay of the medullary elements."[1]

Dr. Bodecker then writes: "From my own researches I am convinced that the full truth in regard to the carious process can be established only by a combination of both Abbott's and Miller's assertions. I admit that micro-organisms are the principal cause of the decay of teeth; but only *dead* material will be destroyed by them without the least reaction. Living tissues—i.e., enamel, dentine, and cementum—invariably react upon the invasion of the micro-organisms by an inflammatory process similar to that in other living tissues, in the manner described by Abbott."[2]

* * *

When Dr. Williams had carefully read Bodecker's book through twice, he knew that he could not write a review. He had to write much more or nothing. He believed firmly in the cell theory advanced by Schleiden and Schwann and Virchow, which, as Bodecker wrote in the preface of his book, was antagonistic to Huxley's and Heitzmann's theories. He did not believe in the Reticulum Theory, which he and Black had denounced in 1885. He did not accept the Medullary Theory. And he did not believe at all in the Inflammation Theory of caries. He resolved to undertake such a thorough exposition of what he believed to be fallacies that they should never again trouble dental histology and that the road should be forever after open to progress along right lines. He ordered from Zeiss the finest microscopic and microphotographic outfit that could be prepared and for more than two years gave all the time that could be taken from his practice to intense occupation in the preparation and study of specimens.

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[1] *The Anatomy and Pathology of the Teeth,* page 503.
[2] *The Anatomy and Pathology of the Teeth,* page 516.

CHAPTER IX

"THE FORMATION AND STRUCTURE OF DENTAL ENAMEL"

IN December 1895 Dr. Williams presented before the Royal Philosophical Society of Great Britain[1] the first of his conclusions from the studies undertaken after reading Dr. Bodecker's book, under the title, *On the Formation and Structure of Dental Enamel.*[2] At this time there was general agreement among histologists as to those stages of tooth development which precede the formation of dentine and enamel, but there was great difference of opinion as to the processes by which dentine and enamel are formed. This presentation by Dr. Williams did not include any studies of the dentine.

As to the methods of enamel formation, histologists seemed to be divided into three groups. One, which included Professor Carpenter, Sir John Tomes and later his son, Charles Tomes, Waldeyer, Wedl and others, believed that enamel was formed by direct calcification of the ameloblasts. Another group, which included Professors Huxley and Schäfer in England, Spee in Germany and Andrews and Sudduth in America, believed that the ameloblasts were not directly calcified to form enamel but that they were active agents in producing the material from which the enamel was formed. A third group, consisting of Heitzmann, Bodecker and Abbott, believed that the ameloblasts broke down into medullary corpuscles which became calcified to form enamel.

Dr. Williams set himself to examine each stage in the formation of enamel with such minute care as to enable him to show which of these theories was correct and why. He knew from experience that the highly technical processes by which specimens for microscopic study must be prepared and the extreme difficulty attending observation of minute and delicate structures might easily mislead any microscopist who confined himself to the study of a few tissues or who fell into the habit of using only one or two methods of preparing those tissues for examination under the microscope. He knew that if the microscopist studied many tissues and used many methods of preparing specimens, he was less likely to be misled by the effects of reagents upon tissues and he might be led to a more correct understanding of all tissues by learning a little from each.

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[1] The Royal Philosophical Society of Great Britain has been, since its foundation, the foremost scientific and philosophical society in the world. The papers read before this Society have almost uniformly marked high peaks of intellectual achievement. The epoch-making presentations by Newton, Faraday, Tyndall, Huxley, Rayleigh, Lister and Darwin have been made first to this Society. The Society occasionally extends invitations to non-members to make presentations which it desires to hear. It was in response to such an invitation that Dr. Williams appeared before it.

[2] The substance of this presentation is printed in *The Dental Cosmos* of 1896.

He therefore prepared specimens from human embryos in all stages of development and from cats, dogs, sheep, hogs, cows, monkeys, mice, rats and guinea-pigs. He utilized practically all the known methods of preparing material, some of which was cut fresh and some immediately after fixing, by various processes. Other material was fixed and hardened by a great variety of processes and embedded in balsam, or decalcified by different acids and embedded in paraffin and celloidin. Because of the importance of staining as a means of identification he used more than thirty different stains and combinations of stains. To guard against errors which might result from any particular method or medium in mounting, specimens were mounted in balsam, in Farrant's medium, in glycerol, in sulpho-carbolate of zinc in glycerol, and in other preservatives. Some of the sections were cut on the freezing microtome, and others on Minot's microtome. Dr. Williams prepared all specimens with his own hands and took his own photomicrographs. The illustrations of his papers were from untouched photographs which he had taken. Although they were published nearly thirty years ago, they are unexcelled up to this day. Something of the excellence of the work can be understood when it is known that the illustrations in this chapter and the next are made by rephotographing the prints of these illustrations from *The Dental Cosmos* of 1896 and 1897.

Stages In Tooth Formation

If we review briefly and in simple terms the stages of tooth formation which precede the formation of dentine and enamel, we shall understand much better the contributions which Dr. Williams made to the knowledge of the later stages. The membrane lining the oral cavity in the human embryo presents three layers, the undermost of which is known as the "columnar layer." Early in the history of the embryo this columnar layer changes form along what will be, at a much later date, the tooth row of each jaw. By forming a fold the columnar layer dips into the underlying tissues. At each point where a tooth is to be located, except some permanent molars, the fold continues to dip into the tissues until a cord is formed. The beginning of this cord is named the "tooth bud." The end of each cord in the submucous tissue enlarges and changes form until it looks somewhat like the bowl of an inverted cup. The histologists called the enlarged portion of the tooth bud the "enamel organ." It is shown in Figure 1[1]. They were agreed that the cells bounding the enamel organ were columnar epithelium, that the center of the cord was filled with cells of cuboidal epithelium and that the inner portion of the enlargement of the enamel organ was filled with a delicate structure known as the "stellate reticulum," which is illustrated in Figures 2[2] and 3[3]. Between the stellate reticulum and the columnar cells on the concave side of the enamel organ, to which cells was given the special name of "ameloblasts," were two or three layers of horizontal cells known as the "stratum intermedium." The group of histologists first referred to in this chapter believed that the ameloblasts secreted from the blood the calcific material essential for forming the enamel and deposited it within themselves, that is, inside the ameloblasts. The second group thought the ameloblasts secreted the material and deposited it outside themselves. Dr. Williams was able to extend the knowledge of the forms and functions of the stellate reticulum, the stratum intermedium and the ameloblasts.

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[1] *The Dental Cosmos,* 1896, page 103.
[2] *The Dental Cosmos,* 1896, page 105.
[3] *The Dental Cosmos,* 1896, page 284.

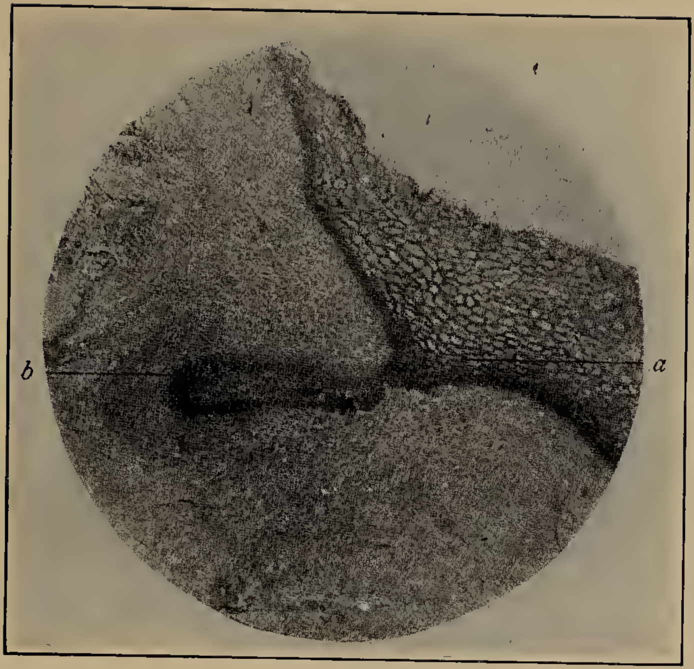

FIG. 1

SECTION OF FACE OF EMBRYO PIG. × 80.
a—Epithelial band from which the cord or pouch of the enamel organ is given off, as shown at *b*.

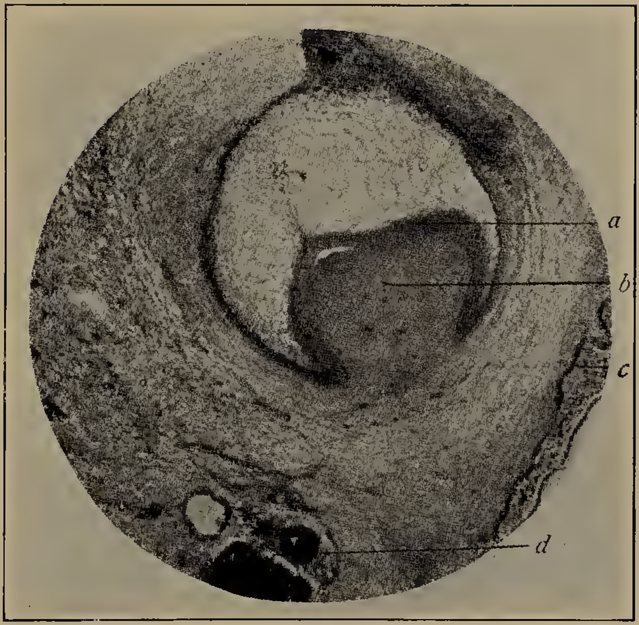

FIG. 2

SECTION OF JAW OF EMBRYO PIG SHOWING DEVELOPMENT OF MOLAR TOOTH. × 80.
a—Formation of ameloblasts. *b*—Dentinal germ. *c*—Formation of trabeculæ of bone. *d*—Formation of blood vessels and nerves. Above *a*—Stellate reticulum.

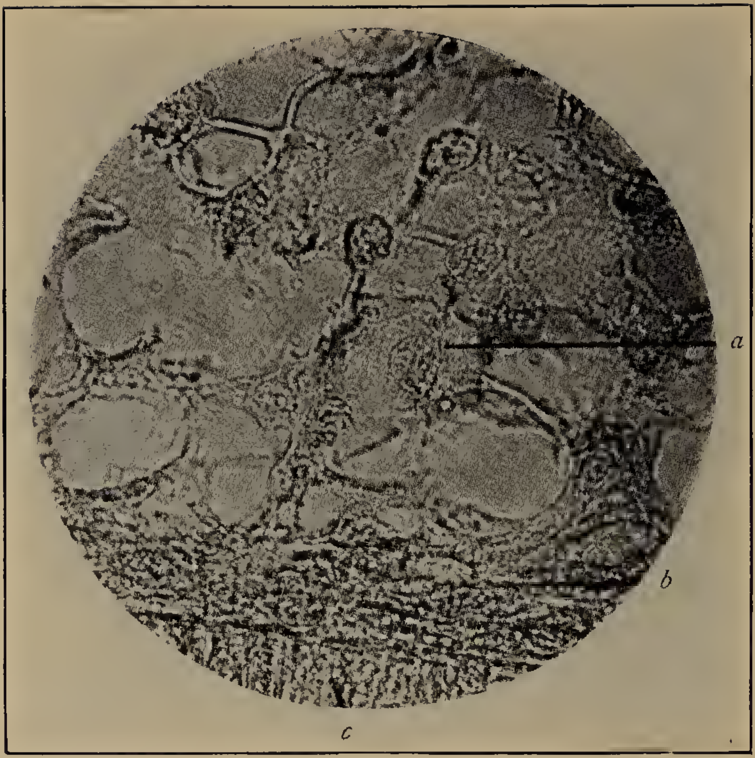

FIG. 3
Section of Developing Tooth of Human Embryo. × 1000.
a—Large nucleated cells of middle layer (reticulum) of enamel organ. *b*—Stratum intermedium. *c*—Ameloblasts.

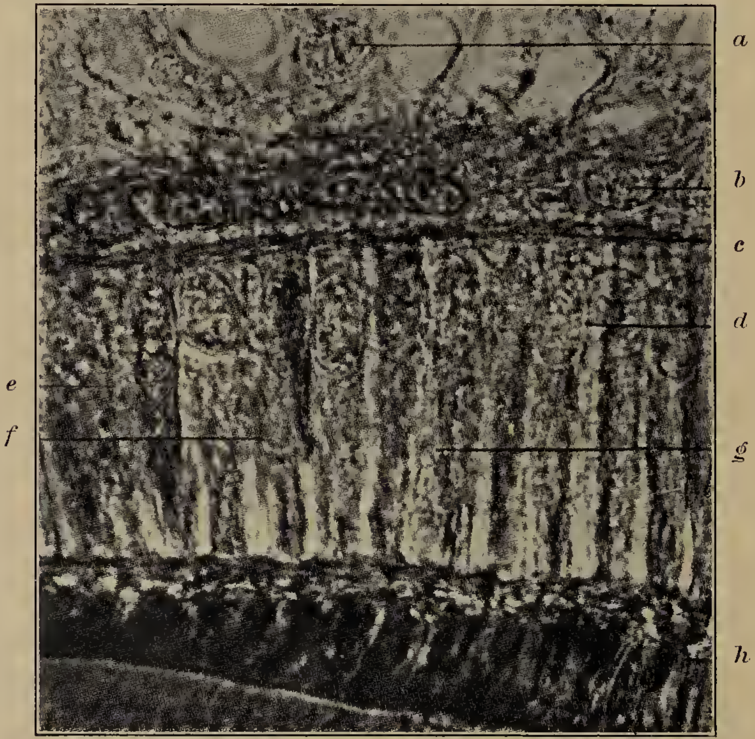

FIG. 4
Section of Developing Tooth of Human Embryo Near Seventh Month of Fetal Life. × 2500.
a—Nucleus of large, granular cells of middle part of enamel organ. *b*—Nucleus of cell of stratum intermedium. *c*—Outer ameloblastic membrane showing several layers. *d*—Nuclei of ameloblasts showing double rim and radiating processes. *e, f, g*—Enamel globules in ameloblasts. *h*—Enamel rods.

STUDIES OF THE STELLATE RETICULUM

In 1883, in the course of his discussion with Professor Garretson, Williams had been able to show that Garretson had been misled, as to the method of enamel formation, by slides in the preparation of which the stellate reticulum had been washed away. At that meeting Williams showed slides in which the more durable portions of the stellate reticulum, that is, the cell membranes and intercellular structure, had been preserved. When he began the studies here described, in 1894, the methods in general use for the preparation of microscopic specimens destroyed all of the stellate reticulum except the cell membranes. The membranes were mistakenly thought to be the entire cells and, because of their starlike projections from points where cells were in contact, the tissue received its name. By improvements in technic Dr. Williams was able to preserve some of the very delicate and watery cells of this tissue in such perfection that the nuclei could be seen, even on the printed page, as shown in Figure 3. He found reason to believe that this tissue is a storehouse for the calcific materials to be used during the early stages of enamel calcification. When calcification is well under way, this tissue disappears. Dr. Williams showed that in the persistently growing teeth of the rodents there is never any stellate reticulum, so it is not essential in all stages of enamel formation.

FORM OF THE STRATUM INTERMEDIUM

Little was known about the function of the stratum intermedium. During the first part of enamel calcification a great quantity of calcific material is required very quickly. This material passes from the stellate reticulum through the stratum intermedium into the ameloblasts. Later, when calcification is proceeding more slowly, the stellate reticulum disappears. The outer epithelial layer of the tooth bud is then brought into contact with the stratum intermedium. The blood vessels which surround the tooth bud then send capillary loops into the stratum intermedium. The cells of the stratum intermedium arrange themselves around the capillary loops, and the stratum intermedium is from that time on a typical secreting organ and takes from the blood stream the calcific material necessary in enamel formation. As a result of his deductions, Dr. Williams announced that the enamel organ of the human teeth, consisting of the stratum intermedium and the ameloblasts, is a true secreting organ. The correctness of this statement was seriously questioned for nearly thirty years, but it is now well established. Mr. J. H. Mummery, after extensive investigations during which he found in fishes a complete confirmation of the typical arrangement in the continuously growing teeth of the rodents, gave his entire endorsement to Dr. Williams's designation of the enamel organ as a secreting organ.

Course of Enamel-forming Material

The calcific material intended for the enamel, which is generally referred to as calcoglobulin, is passed along at first from the stellate reticulum, and later from the stratum intermedium, into the ameloblasts. The details of all that happens next are not yet known. The material passes along the long diameter of the cells (Figure 4[1]) and either calcifies the ends of the cells next to the dentine or passes outside the cell membranes and calcifies there. During these studies Dr. Williams decided that enamel formation is not the result of the deposition of a single product of the enamel organ and that enamel is a much more complex substance than had previously been supposed, as to both the nature of the material supplied by the enamel organ and the structure of completely formed enamel.

Structure of the Ameloblasts

Each ameloblast is composed of a cell membrane, a nucleus, an easily visible internal structure of protoplasmic threads irregularly arranged in a network known as the "reticulum of the cell" (which should not be confused with the reticulum of the entire body predicated by Heitzmann), and colorless protoplasmic material. Dr. Williams was able to demonstrate the existence of an extremely thin membrane, in which no structure could be seen, between the stratum intermedium and the ameloblasts and a similar membrane between the ameloblasts and the enamel already formed.

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[1] *The Dental Cosmos*, 1896, page 289.

These membranes must have had both structure and function because they stained differently from the adjacent tissues. It looked as if they might be formed in each case by the membranes limiting the ends of the ameloblasts. On several occasions Dr. Williams thought that the membranes limiting the sides of the ameloblasts showed the same staining, but the extreme thinness and low visibility under even very high powers, taken with the possibility of errors of refraction, made him uncertain. As the enamel is deposited, the ameloblasts withdraw, until with the completion of the destined thickness of enamel they become modified in form into flat cells, which constitute Nasmyth's membrane. But the protoplasmic threads which run irregularly lengthwise of the ameloblasts do not withdraw. The calcific material is deposited in and around them, as if it held them in place. When the membrane limiting the end of the ameloblasts next to the formed enamel withdraws, these protoplasmic threads project through the membrane into the enamel. And one group of such threads, with the calcific material deposited about them, forms one enamel rod.

Calcific Material Rhythmically Deposited

The calcific material is not deposited among the protoplasmic threads at an even and continuous rate so that an enamel rod is of even diameter from end to end. It is deposited in "waves of globules," as if it accumulates in the ameloblasts until a certain tension is reached, perhaps as the result of the formation of a globule of certain size. The globules are then expelled from all the ameloblasts of a given enamel organ at the same time. This time of expulsion might be called the "crest of the wave." A "resting period" follows during which calcific material accumulates within the ameloblasts up to the point of tension. As the result of the deposit of the calcific material in globules which do not completely "fuse" with the last preceding globules, the crest of each wave is registered by a varicosity in each enamel rod, and the resting period is marked by a constriction between varicosities in each rod. The constrictions are filled with the inter-rod cement-substance. The recurrence of the resting periods between the waves thus accounts for the cross striations seen in human enamel rods.

Dr. Williams adopted the name "enamel rods" in preference to the former name of "enamel prisms" because the term "prism" is here misleading. The rods are not prismatic in form, except in rather rare instances. They are usually irregularly round, and between them are left spaces which are readily distinguishable under the microscope. These spaces are more important than might appear at first glance. When the calcific material deposits in and about the protoplasmic threads, giving to each rod a protoplasmic structure, the same sort of calcific material deposits in the spaces between the rods. Because there is no structure in these spaces, the material there is less resistant to the agents which destroy enamel. The "inter-rod substance," as it has come to be known, differs from the rod substance only in that it lacks the protoplasmic threads.

* * *

Dr. Williams's demonstration of the way in which enamel is formed was so clear and conclusive and it so effectually demolished the Heitzmann theory that that theory has never been heard from since. Williams showed that the functioning power in the enamel organ does not reside in a reticulum composed of protoplasmic strings and holding within its meshes a living but subordinate protoplasm, but that the activating principle works through the individual cells. He showed that the columnar epithelium does not break down into medullary bodies and then into ameloblasts, but that the term "ameloblasts" is merely a special name for that section of the columnar epithelium which lines the concave surface of the enamel organ and that those cells remain unchanged in general character until the predestined thickness of enamel is formed.

He was unable to demonstrate the existence of organic fibers *between* the enamel rods, though they constitute, when calcified, what might be called a "framework" within each enamel rod.

The construction of Nasmyth's membrane, which appears on the outer surface of the enamel after calcification is complete, has been the subject of much speculation. Dr. Williams has recently become convinced, as a result of his studies of teeth of rodents, that this membrane is simply the transformed remnants of the ameloblasts, which have become cornified, that is, more like horn and nails than like enamel. This belief is corroborated by histological studies recently completed by Dr. Williams and is supported by the fact that this membrane can be raised from the completely calcified enamel by the use of acids.

CHAPTER X

"A Contribution to the Study of Pathology of Enamel"

FOR more than twenty centuries men have sought to learn what causes decay of human teeth. It seems that every theory which has the slightest plausibility has been advanced and has had its believers, sometimes for hundreds of years. For two thousand years it was believed that the stagnation of depraved juices within the teeth caused decay. The belief that decay arises from disturbances of nutrition has been held by some since the time of Galen, 131 A.D. For many centuries worms were believed to be an essential factor in the origin of decay, and this belief is said to be still current among the lower classes in some countries. The theory that decay of the teeth is an inflammatory process had its first faint beginnings with Galen and its last and most powerful defense from Heitzmann, Abbott and Bodecker in 1894. The book in which that defense appeared was endorsed as a textbook by the National Association of Dental Faculties. Other theories have ascribed the origin of decay to putrefaction, chemical dissolution, electrocial dissolution, parasites, imperfections or weaknesses of the tooth structure.

Dr. Miller's Statement

In 1890 Dr. W. D. Miller, then resident in Berlin, published in book form his now classical researches into the causes of decay of the teeth.[1] He demonstrated that a considerable portion of the bacteria found in the mouth caused fermentation of starches and sugars, with the production of lactic acid. In view of the developments within the profession, during recent years, the following paragraph from the preface of his book will be found interesting:

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[1] *The Micro-Organisms of the Human Mouth.*

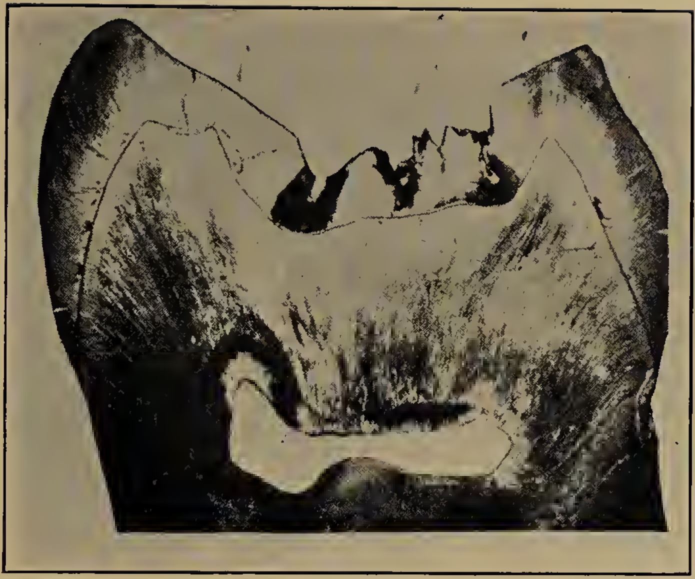

FIG. 5
Antero-posterior Section of Lower Molar, Human. × 12.
Showing defects of structure in vicinity of sulci.

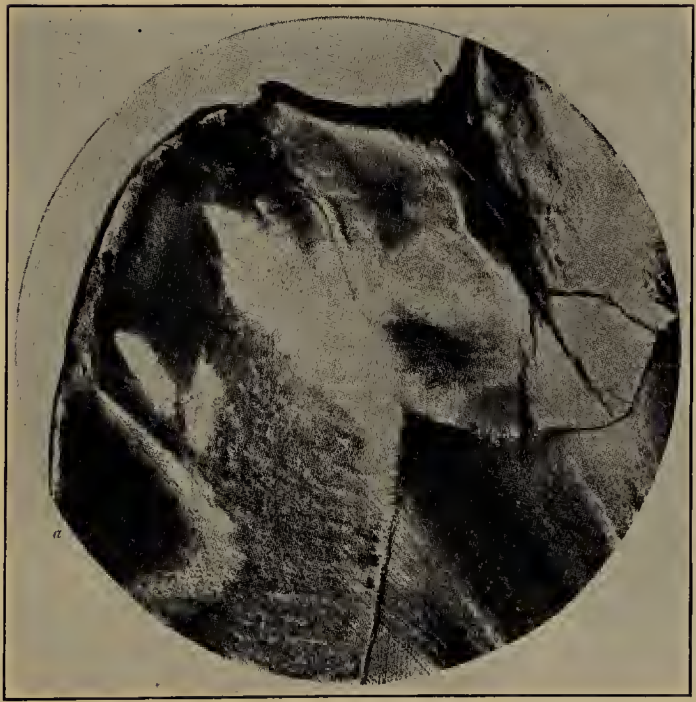

FIG. 6
Section of Cusp of Lower Molar, Human. × 75.
Showing so-called "white spot," *a*, and also other defects of structure.

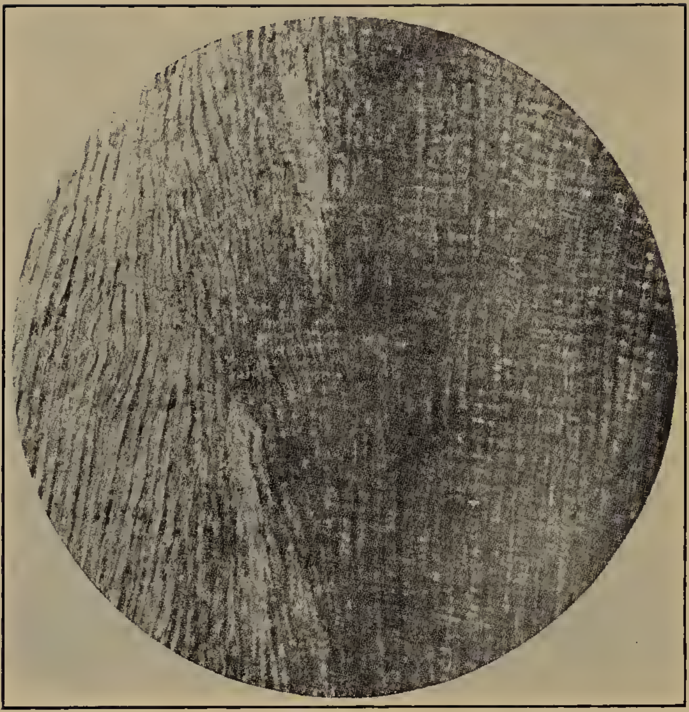

FIG. 7
Margin of Section Through "White Spot" Shown in Fig. 6. × 500.

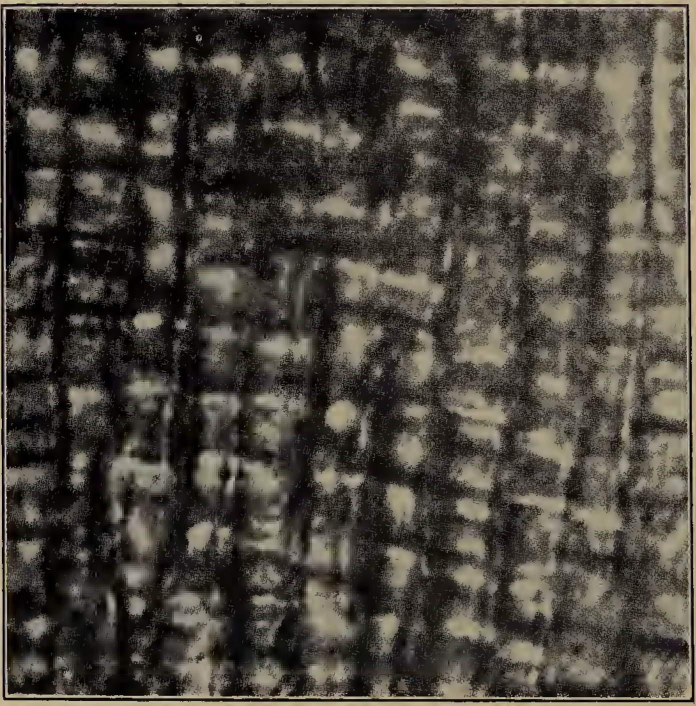

FIG. 8
A Portion of "White Spot" Shown in Fig. 7. × 2000.

"It has been established beyond all question that myriads of microorganisms are constantly present in the human mouth and that these, under favorable circumstances, are capable of manifesting an action of the utmost significance upon the local as well as the general health of the patient. Not alone are they responsible for the vast majority of those diseases of the teeth and contiguous parts which the dental surgeon is called upon to treat, but they also give rise to other local and general disorders of the most serious nature."

The fundamentals of Miller's view as to the causes of dental decay may be given in a few words, adapted from his book, as follows. Dental decay is a chemico-parasitical process consisting of two distinctly marked stages: decalcification or softening of the tissue by the action of acid and dissolution of the softened portion by bacterial action. Decalcification of the enamel practically signifies its total destruction. Since fermentation in the mouth gives rise to lactic acid and since dilute solutions of lactic acid speedily decalcify tooth tissue, there can be little doubt that decalcification is produced largely by this acid. The first indication of decay of enamel is loss of the polish natural to the enamel. Then a white spot appears. A sharp instrument will detect a roughness. The inter-rod substance of the enamel is decalcified, the enamel rods washed away and a cavity results.

COMPREHENSION WAS DIFFICULT

Along with the development of scientific knowledge in the profession there grew up a spirit of inquiry as to what the causes of decay of the teeth might be. As Dr. Kirk said in an editorial in *The Dental Cosmos* in 1897, apropos of the researches by Dr. Williams, the dental profession was compelled to bear the reproach of being wonderful patchers-up of broken-down dental organs, but it had accomplished but little in the prophylaxis of the teeth against the carious process. The more thoughtful dentists felt that before they could protect teeth against decay they must know what caused decay. The subject was so technical, however, that in spite of their interest and need the rank and file of the profession could have little knowledge of the subject. They listened attentively, but most of them were compelled to accept the opinions of men in whom they had confidence because of good work in other and more easily understood fields. The errors in histology and pathology into which such leaders sometimes fell may be illustrated by the statement of one of them, even after the publication of Miller's book, that microorganisms play no important part in dental caries. Even as late as 1897 by no means all of these leaders accepted Miller's conclusions, and the scarcely less important researches of G. V. Black were received, generally, in silence or openly expressed doubt. The result was that the professional man was mentally very much at sea.

What will probably prove to have been the last defense of the theory that dental decay is an inflammatory process was made by Heitzmann, Abbott and Bodecker against Williams, Sudduth and Black in New York in 1885, at the meeting which has been described, and was continued by Bodecker through the publication of his book in 1894. Heitzmann, Abbott and Bodecker were able, aggressive and influential men, all of whom had done excellent work of one form or another. Many dentists had confidence in them and accepted their conclusions.

* * *

When Dr. Williams had, for the time being, finished his studies on the formation of human enamel and the results had been presented before the Royal Philosophical Society of Great Britain and in New York, he undertook the preparation of the results of extensive studies into the origin of decay of the enamel. During the preparation of the papers his old friend and classmate, Dr. W. W. Walker of New York, called upon him in London, learned what he had been doing, saw the demonstration he was prepared to make and besought him to make the presentation in America. The following year was to mark the thirtieth anniversary of the New York Odontological Society, and upon his return to New York Dr. Walker arranged for Dr. Williams to read his paper at the anniversary meeting. After a voyage which was filled with discomfort and actual danger from gales and

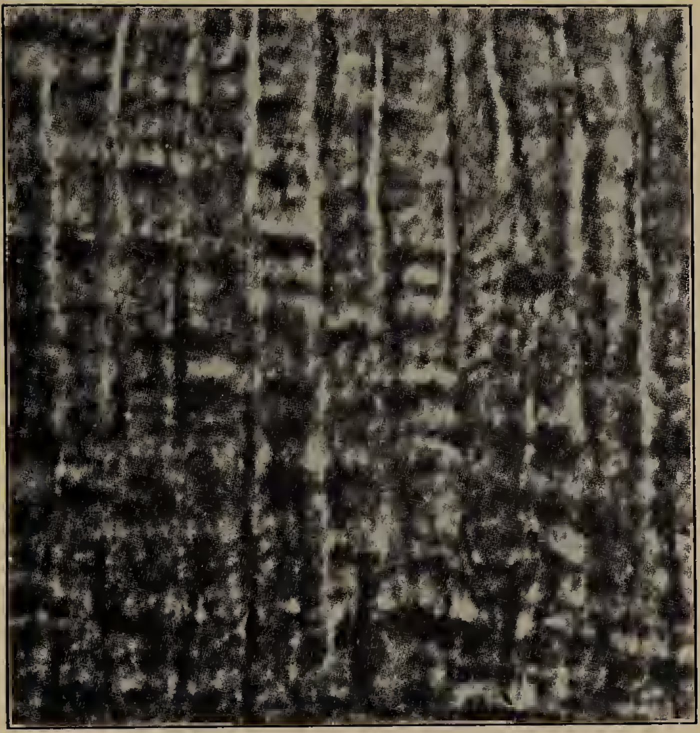

FIG. 9
SECTION THROUGH HUMAN ENAMEL SHOWING FIRST STAGES OF DECAY.
× 2000.

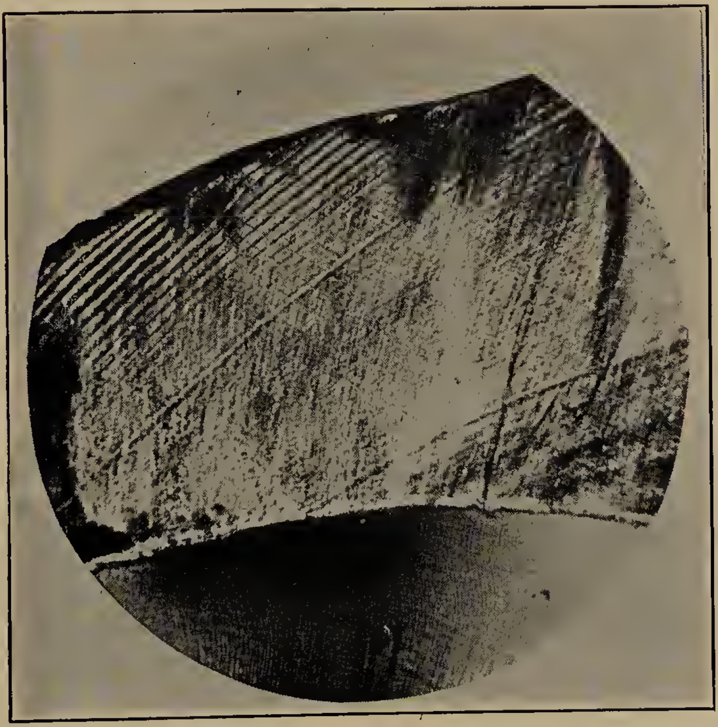

FIG. 10
SECTION OF HUMAN ENAMEL SHOWING APPEARANCES PRODUCED BY
ACID OF DECAY. × 100.

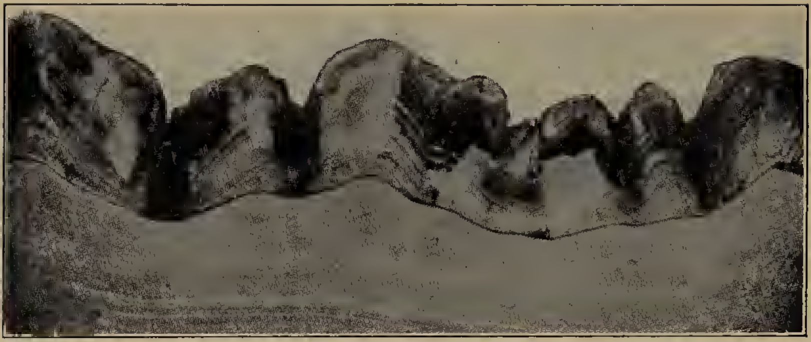

FIG. 11
SECTION THROUGH GRINDING SURFACE OF MOLAR OF GORILLA. × 20.
Shows deep and numerous sulci and many other defects of structure.

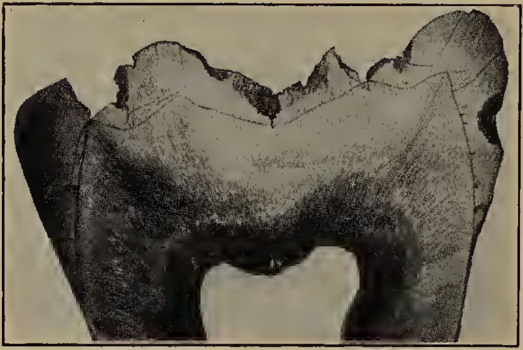

FIG. 12
ANTERO-POSTERIOR SECTION OF UPPER HUMAN MOLAR. × 10.

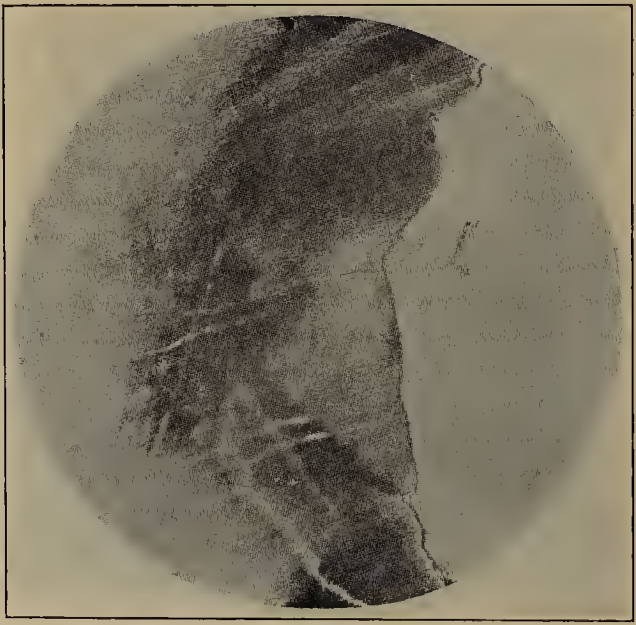

FIG. 13
SECTION THROUGH APPROXIMAL CAVITY SHOWN IN FIG. 12. × 100.

collision of the steamer at sea with either wreckage or ice, Dr. Williams landed in New York about New Year's, 1897, and read his paper before the Odontological Society on January 12th. This paper bore the title, *A Contribution to the Study of Pathology of Enamel.*[1]

There was a note of disappointment for Dr. Williams in this meeting. He had counted heavily on confronting Professor Heitzmann with the evidence which he had accumulated, but he learned, on arriving in New York, that Professor Heitzmann had died a little more than a month before. Before beginning his paper he referred to this event, in part, as follows:

"Eleven years ago, when I read a paper before the First District Dental Society on almost the same subject as I have chosen for tonight, Dr. Heitzmann was my chief antagonist. I came here expecting to find him my chief antagonist tonight. But his lips have been touched with the great and silent eloquence of death, and his voice will be heard no more in our deliberations here. . . . While I have nothing to retract concerning what I have said about him as an interpreter of certain histological facts, yet I have always been aware that he was familiar with important truths not recognized by many who have criticized him severely. He was one of the first . . . to see that the cell protoplasm was not the simple, structureless substance it had long been thought to be. His great error grew out of an attempt to erect a theory on the supposition or assumption that this protoplasmic structure was constant and invariable."[2]

INCEPTION OF DECAY NEVER SATISFACTORILY ILLUSTRATED

Dr. Williams began his scientific presentation by calling attention to the fact that the inception of the process of decay of enamel had never been satisfactorily cleared up, from the illustrative standpoint. If bacteria had ever been photographed and shown as beginning the formation of a cavity on the surface of sound enamel of normal structure, there would have been no possibility of disputing the demonstrated fact, for, obviously, a continuation of the beginning of the process would be all that was required for the complete explanation of the phenomena.

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[1] Published in *The Dental Cosmos,* 1897.
[2] *The Dental Cosmos,* 1897, page 403.

He referred to the theory that decay resulted from degeneration of the tooth tissues by saying that, while well-marked instances of degeneration of the minute structure of the teeth were found, they constituted less than 0.1% of the teeth that decay, and that the profession's need was for some explanation of the cause of decay of teeth with good structure. He sought to dispose of the theory that modern teeth are more frequently degenerative in structure than the teeth of our forefathers by showing that the microscopic defects in modern teeth are common in the teeth of wild races of men, which are largely free from decay, and in many wild animals. He quoted some of Black's conclusions, as follows:

"Imperfections of the teeth, such as pits, fissures, rough or uneven surfaces and bad forms of interproximate contact, are causes of caries *only in the sense of giving opportunity for the action of the causes that induce caries.*"

No Retrograde Metamorphosis in Enamel

He referred to another opinion, apparently as generally and as firmly believed as those he had mentioned, that completely formed enamel might undergo a kind of retrograde metamorphosis and that from this state it might again recover normal condition. The organ by which enamel was formed disappeared upon the completion of the enamel, and even if a mass of lime salts were forced into porous and imperfectly formed enamel, there was then no power to organize these salts into enamel. He then called attention to the fact that there was no evidence that any functional or physiological change ever took place in completely formed enamel. All changes taking place in such enamel must be the result of some agent acting from without, and against the action of any such destructive agent the enamel had no more power of resistance than had salt or sugar against the water in which it was being dissolved.

Imperfections in Calcification

Figure 5[1] shows the imperfections of calcification about the fissures of a molar, which are neither better nor worse than in many teeth which decay and many which do not.[1] Figure 6[2] presents a molar in which the finer structures show a greater departure from normality than in Figure 5. On the left side of this figure is shown a "white spot," probably congenital, which appears dark by transmitted light. This spot is surrounded by a dark zone (light in the picture) of precisely the same appearance as that which surrounds the dark tissue in caries of enamel.

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[1] *The Dental Cosmos,* 1897, page 170.

Figure 7[3] is from the edge of the white spot, just where it passes over into the light zone which everywhere surrounds it. The larger portion of this figure is from the dark part of the white spot, while the left side shows the edge of the lighter zone. In the white spot in this figure the enamel is more granular, it is more deeply pigmented and the enamel rods have not melted together as completely as in the lighter portion. This appearance may be due to a deficiency of the albuminlike material, which, when calcified, forms the inter-rod cement-substance.

Figure 8[4] is from the right side of the white spot shown in Figure 7. It will be seen that the enamel rods and the globular bodies of which the rods are made up are very imperfectly united. Figure 9[5] is from enamel in the first stages of decay, seen under the same power of magnification. The general appearance is alike in both specimens. In both there are spaces between the rods and between the globular bodies. In Figure 8 this deficiency is probably caused by the deficiency of the albuminlike material during calcification. In Figure 9 the cement-substance between the rods and between the globular bodies has been removed by the action of the acid causing decay until the same stage of deficiency of cement-substance has been reached.

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[1] Persons not familiar with the appearance of illustrations made by transmitting light through microscopic sections should remember that portions which are light-colored in the section appear dark in the illustration, and vice versa. The terms "white," "light" and "dark" are used here to describe conditions as they exist in the specimen, which are the opposite of conditions in the picture.

[2] *The Dental Cosmos,* 1897, page 170.

[3] *The Dental Cosmos,* 1897, page 171.

[4] *The Dental Cosmos,* 1897, page 172.

[5] *The Dental Cosmos,* 1897, page 173.

Acid Penetrates Enamel Deeply

The acid products of bacteria often penetrate the enamel to great depth, sometimes passing through the entire thickness of this tissue before the external surface begins to break down. Figure 10[1] is from a photograph of an unstained section of enamel. The zone of dark-colored dentine shown is identical in appearance with ordinary decay of dentine and was undoubtedly caused by the action of the acid of decay which penetrated from the surface of the tooth. The area of affected enamel is shown by the dark boundary lines on each side of the field, but the enamel has not begun to break down.

Tooth Conditions in Men and Apes

Dr. Williams then called attention to a comparison of the conditions as found in human teeth and in the teeth of the anthropoid apes. Figure 11[1] is from the tooth of a gorilla shot in its native wilds. The pits and grooves are larger than in the average human tooth and some of them extend nearly to the dentine and are flask-shaped, so that they are particularly well suited for the propagation of bacteria. There is a coarse stratification of both enamel and dentine. The teeth of chimpanzees, of orang-outangs and of the Syrian Hyrax all show similar characteristics. Dentists who felt that the defects in minute structure of human teeth are due to certain of the diseases of childhood were invited to state whether wild orang-outangs, chimpanzees and gorillas have these diseases.

Difficulty of Illustrating Carious Enamel

Having shown that many of the generally accepted theories as to causes of decay were erroneous, Dr. Williams called attention to the fact that previous writers had treated the subject of decay of the enamel very briefly. This may have been due, in part, to the fact that they found it far from easy to prepare enamel specimens. Even that master of investigation, Dr. W. D. Miller, wrote: "The preparation of specimens of enamel suited for a study of the process of decay is very difficult." Mr. Henry Sewill, then a noted

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[1] *The Dental Cosmos*, 1897, page 175.

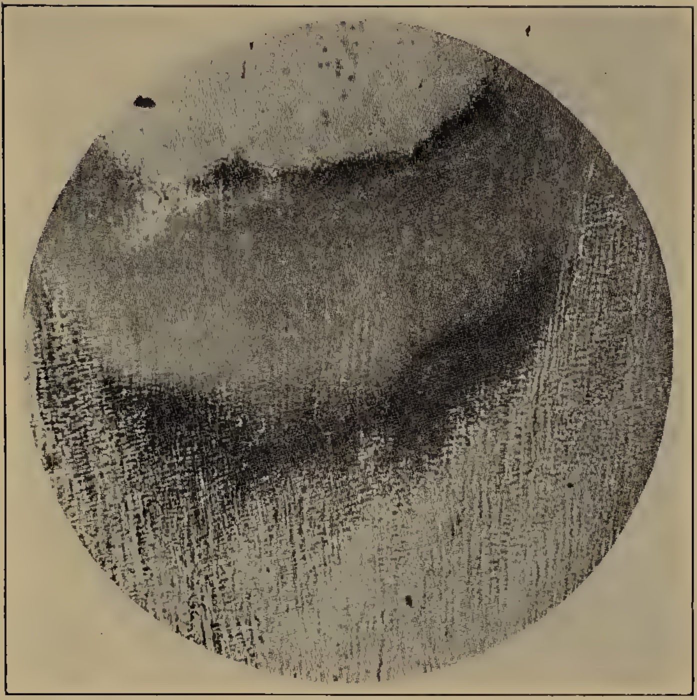

FIG. 14

Section of Carious Enamel Prepared by the Weil Method. × 300. The deep natural stain and general appearance of the enamel indicate very slow decay. In printing, the thinnest part of the negative, where stain was deepest, was "blocked out" to prevent entire loss of detail. Enamel rods are not broken down in this deeply stained part and there is no granular layer. The only appearance of this sort is on surface of cavity, where thick mass of bacteria is shown.

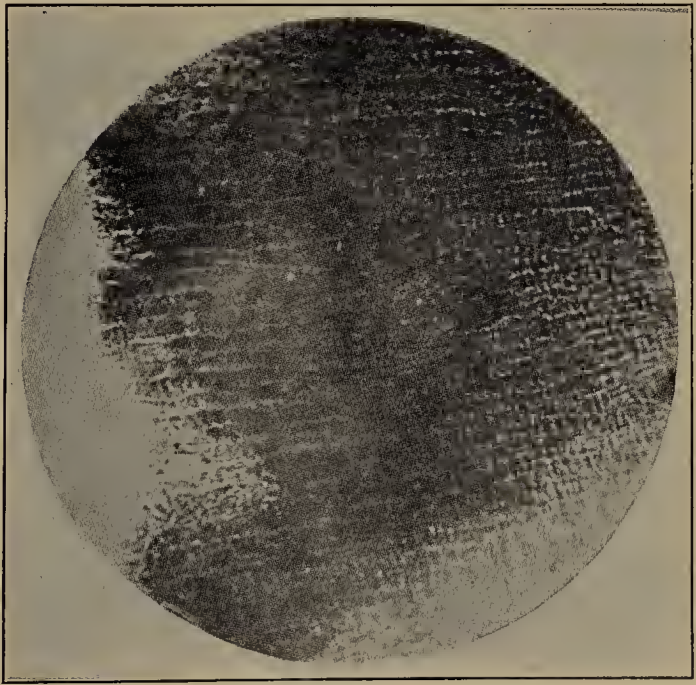

FIG. 15

From a Section of Carious Enamel. × 800. The mass of microorganisms, which has often been spoken of as a granular layer of decomposing enamel, has been torn away from the surface in mounting.

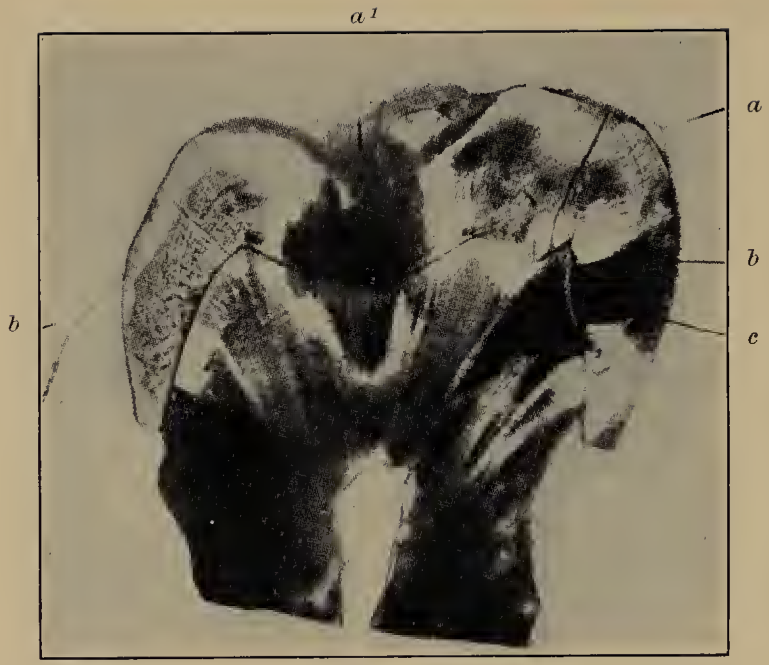

FIG. 16
SECTION OF HUMAN BICUSPID SHOWING COMMENCEMENT OF CARIES. × 12.
a and *a*¹—Appearances caused in enamel and dentine by the acid of decay. *b* and *b*²—Shreds of a feltlike mass of bacteria raised from surface of enamel. *c*—A cavity, more distinctly shown in Fig. 17.

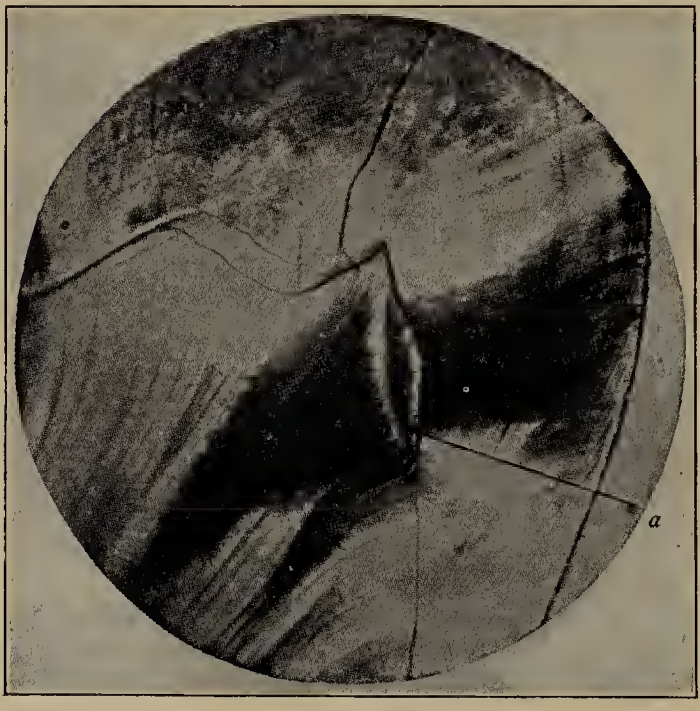

FIG. 17
STAINED AREA OF ENAMEL AND DENTINE SHOWN AT *a* IN FIG. 16. × 50.
a—Cavity formed by acid of decay at line of union of enamel and dentine. The only means of communication between this cavity and surface of enamel is through microscopic canals formed in enamel by acid excreted on surface by bacteria.

investigator, said: "To cut a section of carious enamel sufficiently thin for examination under high microscopical power is impossible." Illustrations of carious enamel were very rare. There were no photographs or drawings of it in the *American System of Dentistry.* Dr. Black made a masterly summing up of the whole subject but no definite statement as to the exact process of the inception of caries. The last edition of Charles Tomes's *Dental Surgery* showed only one illustration of carious enamel, and this was from *The Dental Cosmos* of 1879.

It was evident that if Dr. Williams was to study the beginning of enamel caries through the microscope his first task was to develop a method of doing what other investigators said was difficult or impossible, that is, to grind enough specimens of enamel to permit an exhaustive study and to grind them thin enough to permit the use of high microscopical powers. He devised a method and ground more than four hundred specimens of carious enamel to a thinness of less than half the thickness of this page. He learned also how to prepare and mount the specimens in spirits and glycerol and thereby assure a truer image and the utmost naturalness of appearance.

Appearance of Decaying Enamel

Figure 12[1] illustrates a section of an upper molar showing caries of the enamel on the occlusal and approximal surfaces. The small cavity on the mesial surface, when examined under a power of 100 diameters, appears as in Figure 13[1]. Note the usual staining of the enamel and the marked definition of the rods and the sections of which they are composed, as a result of the penetration of some acid.

On the margin of the cavity is seen what has sometimes been referred to as a granular layer of nearly decomposed enamel. Figure 14[2] shows a section of deeply pigmented and slowly decaying enamel. The rods do not break into a granular appearance. The ends of the rods, which form the floor of the cavity, have the usual appearance of rods which are being acted upon by some acid. The granular appearance is caused by the mass of bacteria which lines the cavity. Figure 15[1] shows the border of the decaying enamel magnified 800 diameters. The cement-substance between the rods and between the globular bodies composing the rods has been partly removed by acids which have penetrated deeply into the substance of the enamel.

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[1] *The Dental Cosmos*, 1897, page 286.
[2] *The Dental Cosmos*, 1897, page 287.

DEMONSTRATION OF THE BACTERIAL PLAQUE

In one respect every specimen of decaying enamel showed precisely the same appearance. Lining the cavity or covering the surface where decay had commenced there was always to be seen a thick, feltlike mass of acid-forming organisms. "This mass of fungi is so dense and adhesive as to make it highly improbable that the enamel is affected, except in rare or special instances, by any acid other than that which is being excreted by the bacteria at the very point where they are attached to the enamel. The thick, glutinouslike mass of fungi also prevents the excreted acid from being washed away, so it exerts its full chemical power upon the calcific tissue."[2]

The appearances of enamel at the beginning of decay are shown in Figure 16[3]. The tooth was from the mouth of a woman thirty-six years of age who suffered but little from caries. Although stained, it appeared perfectly sound. There were no opposing teeth, and this tooth was literally covered with a thick growth of microorganisms. The acid products of these fungi had softened the crown of the tooth in several places, although there was not a trace of cavity to be seen on the external surface.

If the spot on the approximal surface in Figure 16 be examined under a high magnifying power, it will be seen that while the destructive agent which caused the discoloration has not broken down the surface it has penetrated the entire thickness of the enamel and produced a cavity of sufficient size so that it can be seen with the unaided eye, after grinding the section, at the line of union of the

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[1] *The Dental Cosmos*, 1897, page 288.
[2] *The Dental Cosmos*, 1897, page 296.
[3] *The Dental Cosmos*, 1897, page 289.

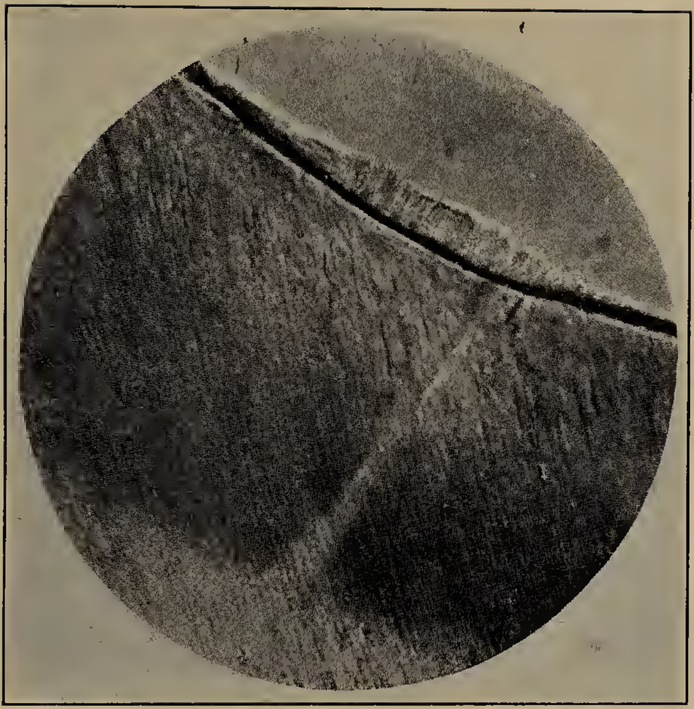

FIG. 18
SECTION OF NORMAL HUMAN ENAMEL FROM APPROXIMAL SURFACE OF BICUSPID SHOWING MICROORGANISMS ATTACHED TO NASMYTH'S MEMBRANE. × 200.

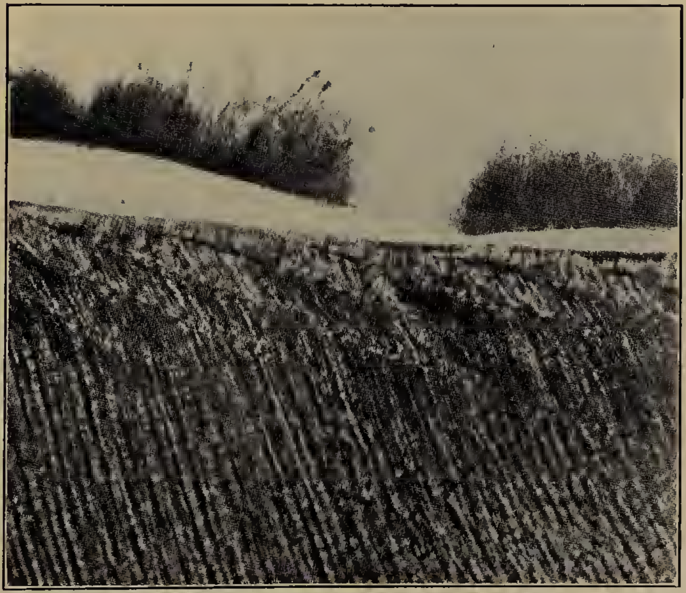

FIG. 19
SECTION OF NORMAL HUMAN ENAMEL. × 350.
Showing thick, feltlike mass of microorganisms slightly raised from surface of the tissue by pressure of cover glass in mounting.

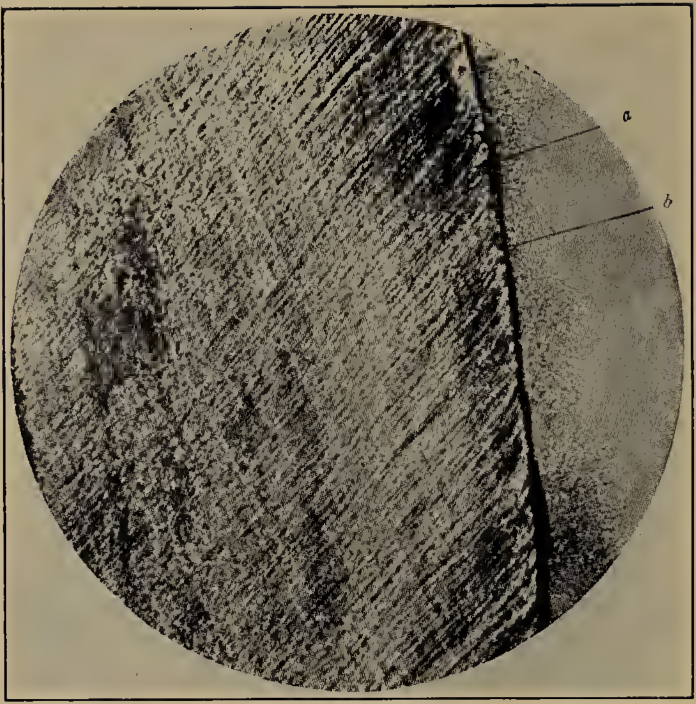

FIG. 20
SECTION OF HUMAN ENAMEL SHOWING MICROORGANISMS ATTACHED TO APPROXIMAL SURFACE OF BICUSPID. × 200.
a, b—Commencement of caries by solution of cement-substance between enamel rods.

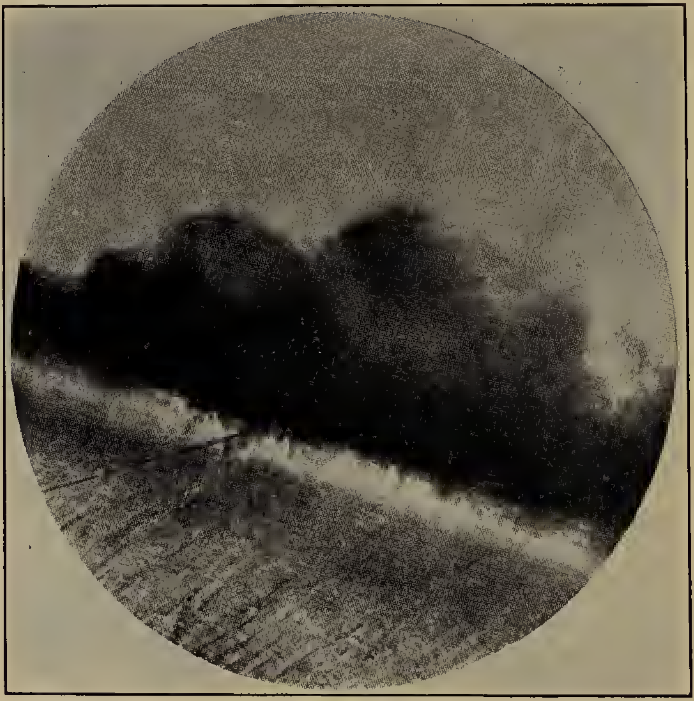

FIG. 21
SECTION OF HUMAN ENAMEL. × 350.
Shows deeply stained mass of microorganisms attached to surface and further action of acid in dissolving cement-substance and forming V-shaped spaces between enamel rods.

dentine and the enamel. This cavity is filled with loose and decomposing particles of enamel (Figure 17[1]).

If any part of the stained area in Figure 16 is examined under a higher power, it is seen that the cement-substance between the rods has been dissolved out until canals of considerable size have been formed, down which the acid has penetrated to the cavity beneath. These figures and the others which were shown with them give a complete explanation of what has been wrongfully interpreted as a retrograde metamorphosis of enamel. Enamel thus softened by the action of an acid cuts much more easily than sound enamel.

Figure 18[2] shows a mass of bacteria attached to Nasmyth's membrane. In Figure 19[3] Nasmyth's membrane has been destroyed by the action of bacteria, and attack on the enamel has commenced as is shown by the fibrous appearance of the enamel surface, which was more clearly seen on the screen than it is in this picture. The separation between the mass of bacteria and the enamel is caused by the pressure on the cover glass during the mounting of the specimen. Later in the progress of decay the mass of microorganisms is less easily separated from the enamel.

Acid from Plaques Dissolves Enamel

Figure 20[4] shows the mass of microorganisms attached to the approximal surface of a tooth which was free from imperfection of any sort at the point of attack. The enamel in this tooth was very finely formed, but the acid had dissolved out the cement-substance between the rods to form V-shaped spaces on the surface. In Figure 21[5] the microorganisms are shown deeply stained and the focus is adjusted on the surface of the enamel, showing the bacteria entering the V-shaped spaces.

In Figure 22[6], which is from a specimen of very rapid white decay, the acid has almost completely removed the cement-substance and there remain only the fibrous and globular products of the ameloblasts which Dr. Williams described in his previous papers on enamel formation.

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[1] *The Dental Cosmos*, 1897, page 290.
[2] *The Dental Cosmos*, 1897, page 293.
[3] *The Dental Cosmos*, 1897, page 294.
[4] *The Dental Cosmos*, 1897, page 296.
[5] *The Dental Cosmos*, 1897, page 297.
[6] *The Dental Cosmos*, 1897, page 300.

In direct or penetrating decay it is probable that the enamel rods rarely break down by molecular disintegration, as claimed by Dr. Black, but when decay has undermined the enamel and is working from the inner surface of the enamel, molecular disintegration probably occurs.

In Figure 23[1] the acid product of the bacteria is seen to have penetrated between the enamel rods and between the sections, and sections are shown in the mass of bacteria. These sections are either completely dissolved by the acids or thrown out and washed away. Scrapings from an enamel surface undergoing decay are shown in Figure 24[2]. The spaces between the rods, effected by the acid action, are here shown filled with microorganisms. In Figure 15, in which the bacteria were torn from the surface of the enamel in mounting, the effects of their acid upon the enamel surface can be seen.

SUDDEN SUSCEPTIBILITY

"It is a matter of common observation that teeth which have for years been comparatively free from caries are suddenly attacked and for a time decay very rapidly." There is not the slightest ground for a belief that this is due to a degeneration of the tooth tissues. "In all such cases it is evident that some change in the fluids of the mouth has occurred which decreases their inhibitive power over the development of microorganisms." Fermentation is persistent and rapid, and "acid-forming bacteria proliferate rapidly and act with great energy. The observed differences in rapidity of decay, therefore, are primarily due to change in environment, somewhat accelerated or retarded by such peculiarities of structure as have been pointed out.[3] . . .

SUMMARY OF QUESTION OF DECAY

"From the facts now in our possession we may sum up the whole question (of decay of enamel) by saying that if the environing conditions of the teeth are such as to favor

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[1] *The Dental Cosmos,* 1897, page 361.
[2] *The Dental Cosmos,* 1897, page 370.
[3] *The Dental Cosmos,* 1897, pages 368, 369.

FIG. 22

Section of Human Enamel Nearly Decalcified by Rapid "White Decay." Fibrous Substructure of Enamel Finely Shown. × 600.

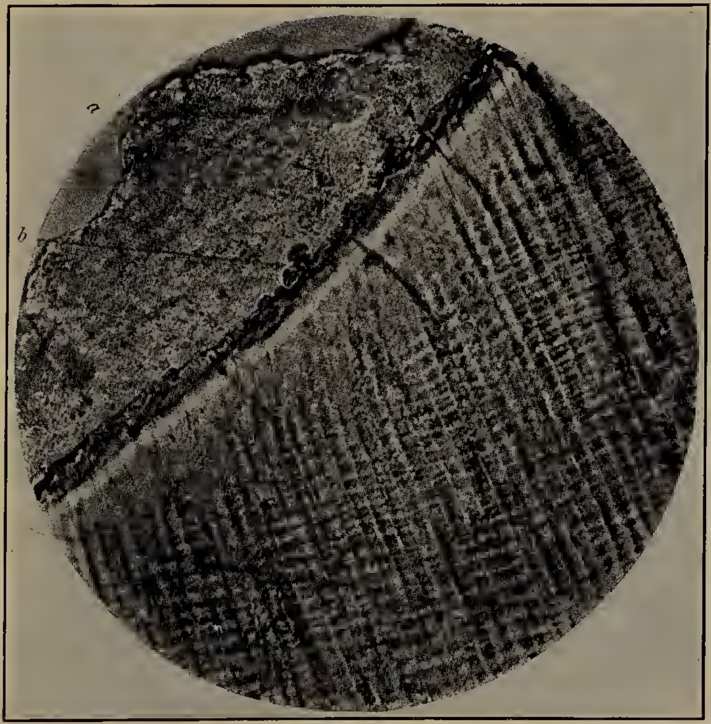

FIG. 23

Section of Carious Enamel Showing Destruction of Tissue by Solution of Cement-substance Around Enamel Rods and Globular Bodies. × 500.

a, b—Globular bodies of enamel rods loosened and set free by action of acid excreted by thick mass of microorganisms attached to surface of tissue.

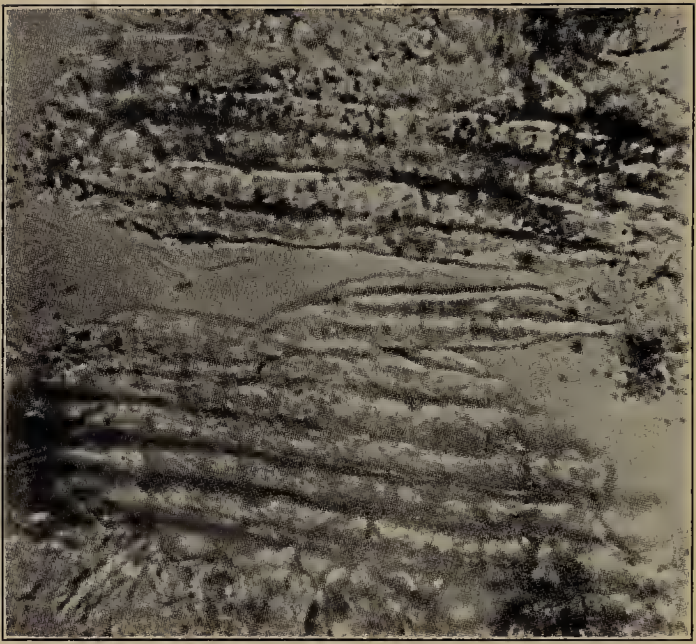

FIG. 24

From Cover-glass Preparation of Decaying Enamel. × 1500. Stained with Squire's carbolic fuchsin. Microorganisms, chiefly micrococci and diplococci, are everywhere seen lying between enamel rods.

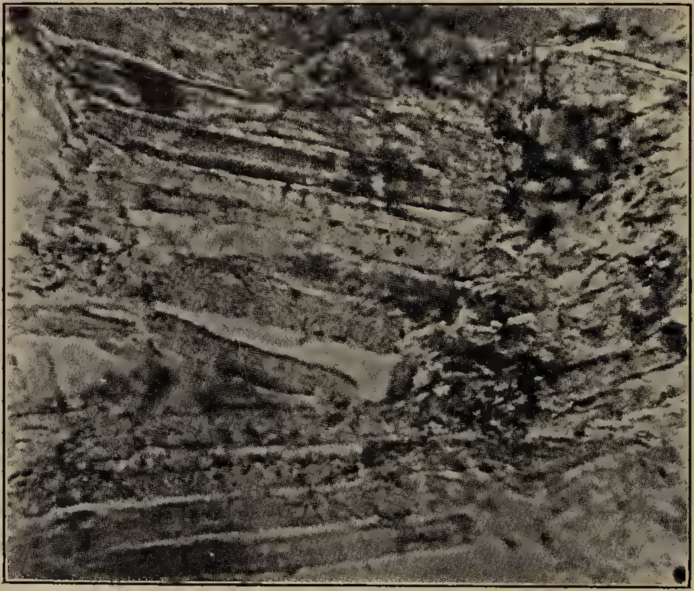

FIG. 25

Showing Final Disruption and Destruction of Enamel Rods Near Margin of a Cavity of Decay. × 1500.

the development and activity of acid-producing bacteria, and if those bacteria are permitted to become attached to the surface of the enamel, it is doomed, although it may be the most perfect that was ever formed. On the other hand, if those environing conditions are not present, the worst enamel will not decay."[1]

The ruin which may be wrought is exemplified in Figure 25[1], where the tumbled and broken remnants are all that remain of that once beautiful structure, the enamel of a tooth.

Discussion by Dr. Black

The report of the proceedings of the New York Odontological Society, in *The Dental Cosmos* for 1897, shows that the discussion was opened by Dr. G. V. Black, who came from Jacksonville, Illinois, especially for this paper, as he had come for Williams's paper eleven years before. He spoke, in part, as follows:

"When we think of the work in the technic alone that has been necessary for the production of the views that have been thrown upon the screen this evening, we see that the labor has been simply enormous. . . . Many of the pictures are a long step in advance of anything that has been shown before. Step by step we move forward, and this evening we have made a very long step. Particularly gratifying to me have been those illustrations of bacteria in position upon the surfaces of the teeth. Do you know how long it has taken to demonstrate that, since it was first . . . shadowed out? Since 1835, when Robertson said, 'Decay is produced by decomposition occurring at the immediate spot where the decay begins.' This is the first time that that demonstration has been given to the public, showing these microorganisms—the agents of this decomposition—exactly in position where the beginning of decay occurs.[2] . . .

"What impels a man to leave his practice day after day and go into his den and labor for the production of such a show as this? . . . It is something within the man that impels him to follow thought after thought, seek more and more into nature's work, into the whys and wherefores of things. . . . What does he get for all this? The satisfaction of having done it; and further, it furnishes us, as a profession, with the basis of treatment.[1] . . .

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[1] *The Dental Cosmos*, 1897, page 374.
[2] *The Dental Cosmos*, 1897, page 404.

"This study (of caries), as I have said, has been going on since the time of Robertson, who pointed out the general fact, seemingly by intuition. He could not demonstrate it." Then came Tomes, Leber and Rottenstein, Milles and Underwood, and then Miller. "I have made a few contentions along this line myself . . . but never arrived at a demonstration. Now Dr. Williams makes a demonstration of it and shows the microorganisms in apposition doing exactly this thing. After his demonstration it is hardly necessary to follow this up further than to impress upon you this one grand fact . . . it is actually demonstrated that it is so by showing the thing in position upon the screen.[2] . . .

Caries Not Caused by Free Acids

"Caries is not caused by free acids of the mouth or by acid saliva. We may have caries going on like wild fire in mouths where the fluids are alkaline or neutral. . . . It is the acid developed by fermentation under those masses of microorganisms in intimate contact with the tissues of the teeth that causes caries, and not the acids that may be afloat in the saliva.[3] . . .

"Many of you perhaps remember the little work I published in *The Cosmos* in 1891 in which I described the tearing down of the enamel and the separation of the enamel rods. . . . I had never been able to get such views of it as you have had this evening. . . . This evening we have had it placed on the screen in such a way that none of you can mistake it. . . . These pictures, if we interpret them correctly, tell us the truth. There has been no tampering with them. . . . The paper of Dr. Williams is not simply a scientific paper, but it is a paper furnishing us a sounder basis of daily practice than we have ever had before."[4]

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[1] *The Dental Cosmos*, 1897, pages 404, 405.

[2] *The Dental Cosmos*, 1897, pages 407, 408.

[3] *The Dental Cosmos*, 1897, page 408.

[4] *The Dental Cosmos*, 1897, pages 408, 410.

DISCUSSION BY DR. H. H. BURCHARD

Dr. H. H. Burchard of Philadelphia followed Dr. Black in the discussion. A few of his remarks were: "We have no choice as to our manner of viewing this work of Dr. Williams; we are compelled to accept it as an irrefutable demonstration. His chain of evidence is quite as complete as is ever demanded. This work marks an historical epoch in dental science. . . . The subjects which Dr. Williams presented cannot be discussed in one evening. . . . . He has given us a firm basis for years of study. As to criticism, his work as presented admits of none. It is a presentation of an absolute demonstration. He, Dr. Miller and Dr. Black have all earned a measure of gratitude from the dental profession and scientific world, which we should gladly accord them now and in all future time."[1]

Drs. R. H. Hofheinz, James McManus, E. C. Kirk, A. W. Harlan and W. Jarvie all spoke in praise of the work which Dr. Williams had done and the presentation he had made.

DISCUSSION BY DR. R. OTTOLENGUI

Near the close of the evening Dr. R. Ottolengui spoke, in part, as follows:

"During the progress of the paper a prominent gentleman asked me, 'Shall you be able to fill a tooth any better tomorrow?' . . . I am able to answer that I shall certainly be very much better able to fill teeth tomorrow. The question that has worried us as to the cause of decay has not only been absolutely answered, but it has been answered in such a way that it immediately disposes of many practical questions. . . . When it is known, as it has been shown so beautifully here tonight, that the active cause of decay passes down between the rods of enamel, what excuse can there be for leaving those sulci, which must be the breeding-place of the bacteria? . . . How can we honestly leave decay in teeth again? . . . In the past we have been able to fill teeth with mechanical accuracy; in the future we should be able to fill them with scientific perfection."[2]

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[1] *The Dental Cosmos,* 1897, pages 410, 412.

[2] *The Dental Cosmos,* 1897, page 415.

CHAPTER XI

"A CONTRIBUTION TO THE BACTERIOLOGY OF THE HUMAN MOUTH"

DR. WILLIAMS'S demonstration of the existence and character of what has since then come to be known as the "bacterial plaque" and its function as the forerunner of caries of enamel was regarded as conclusive by most dentists. There were some, however, who felt that he had not shown that the bacteria found in these plaques were acid-forming organisms and that the demonstration of the function of the plaques in caries was incomplete to that extent.

DR. JAMES TRUMAN'S UNBELIEF

Among these doubters was Dr. James Truman of Philadelphia, editor of *The International Dental Journal,* one of the most forceful writers and teachers of his day in the profession. Perhaps his criticism can be summed up in his words, "Dr. Williams's original pictures and slides . . . demonstrated that the 'gelatinous microbic plaques,' as Dr. Black calls them, were plentifully distributed and that they were leptothrix threads *and not the microorganisms of caries,* hence not acid-producing." Dr. Williams felt that the only proper answer to such criticism was by means of a demonstration that the bacteria found in the plaques were acid-producing organisms. He went much farther and made important additions to the knowledge of oral bacteriology. He presented the results of this investigation in an address entitled *A Contribution to the Bacteriology of the Human Mouth* before the New York Odontological Society on January 17, 1899, and they were published in *The Dental Cosmos* of 1899, from which the material for this chapter, including the illustrations, is taken.

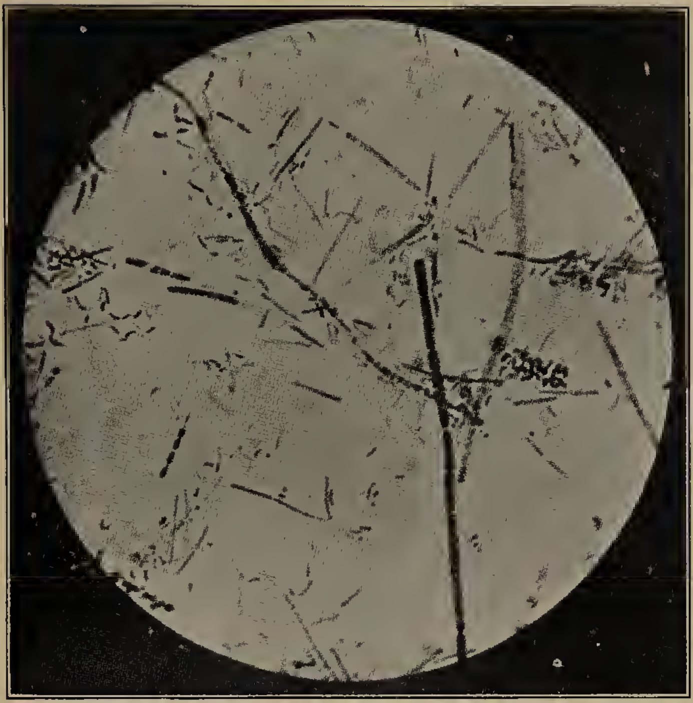

FIG. 26
From scrapings taken from approximal surface of tooth. Shows all of the typal forms of microorganisms found in the human mouth and others which have not heretofore been described. Zeiss obj. 2 mm., proj. oc. 6.

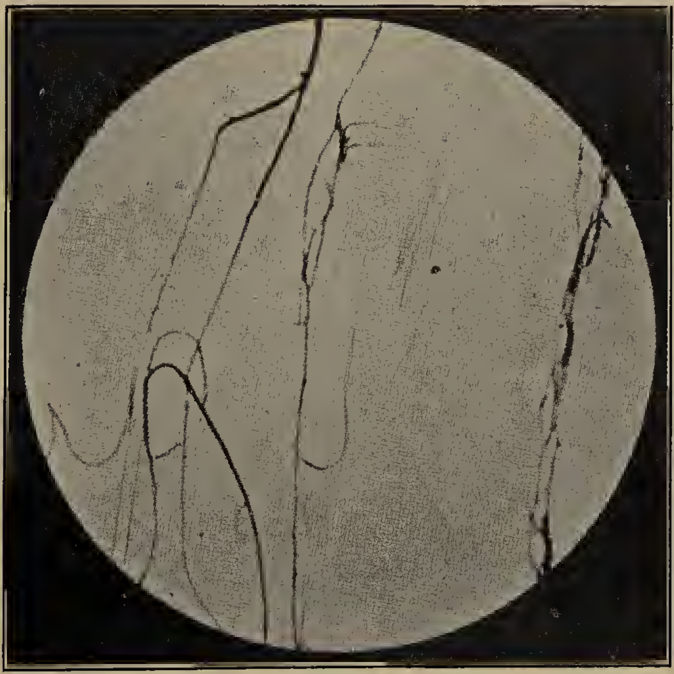

FIG. 27
A mycelial microorganism grown on agar-agar from material taken from scrapings from approximal surface of human tooth. Zeiss obj. 2 mm., proj. oc. 6.

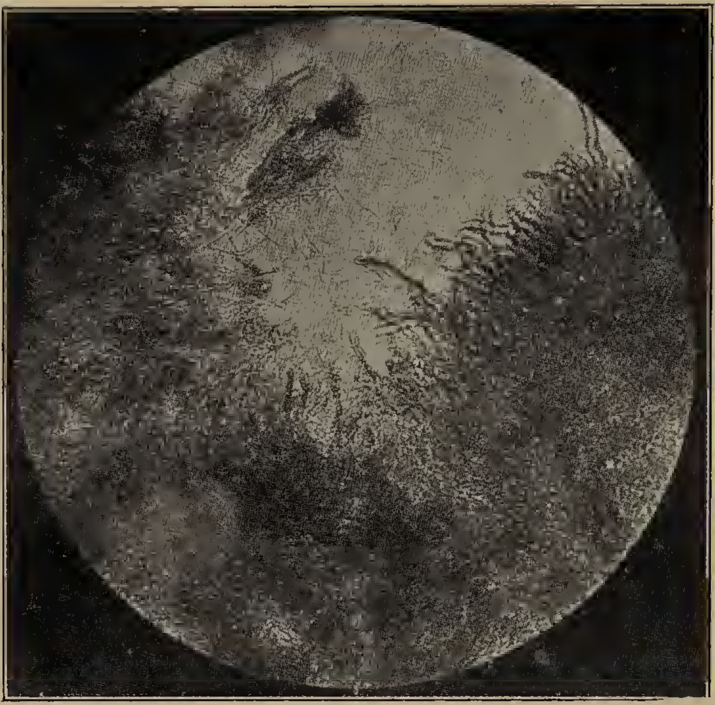

FIG. 28

The material from which this photograph was made, and all of those which follow up to Fig. 41, was obtained by scraping approximal surfaces of teeth after thorough syringing with sterilized water and, in some instances, also after rubbing surface of the tooth with wad of sterilized cotton wool. The gelatinous mass of microorganisms adheres to surface of enamel with considerable tenacity. Scrapings were stained with watery solution of gentian-violet-anilin water and mounted in diluted glycerol. Under power of 400 or 500 diameters places will be found presenting such appearances as shown above.

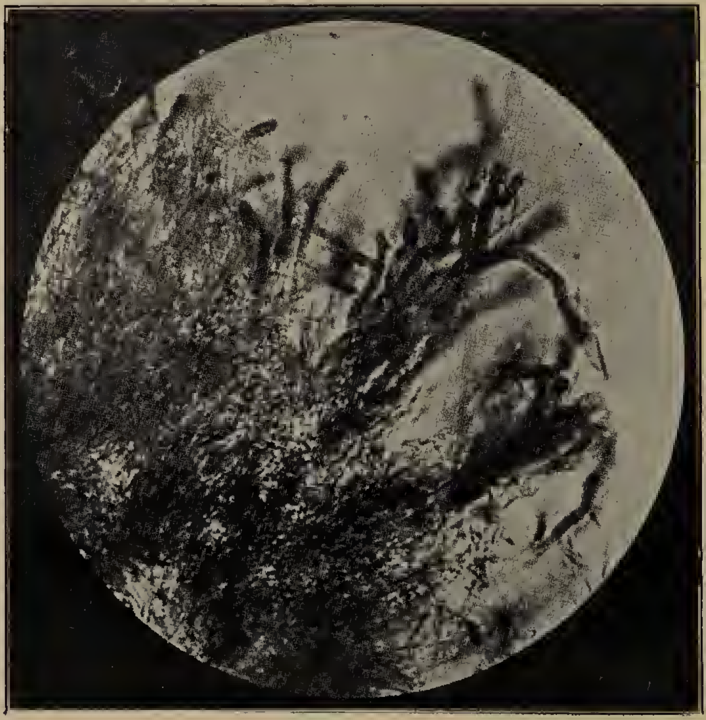

FIG. 29

Fructification heads of Leptothrix racemosa. Zeiss obj. 3 mm., proj. oc. 3.

MANY SPECIES OF THREAD-FORMING ORGANISMS

Dr. Williams began by calling Dr. Truman's attention to the very common error of regarding every thread-forming organism found in the mouth or obtained in pure culture from the juices of the mouth as Leptothrix buccalis, inasmuch as not less than five known species that form threads, and probably twice that number, could be demonstrated. He then explained the technic which he employed to discover the minute characteristics of the organisms and illustrated the demonstration by many photomicrographs, of which only a few can be reproduced here.

Many of the specimens from which Dr. Williams had made photographs illustrating previous demonstrations had been mounted in glycerol. This made it possible to dismount the specimens, wash out the glycerol, remove the microorganisms and make special cover-glass preparations by which their nature could be studied. The use of the same specimens tied this demonstration inseparably to the previous presentation and forestalled any criticism that conditions existed in one set of pictures which had not obtained in the other.

ACIDS PRODUCED BY MANY BACTERIA

Figure 26[1], made from scrapings from the approximal surface of a tooth, shows all the typal forms of microorganisms and several which, up to the time of the writing of this paper by Dr. Williams, had not been described. He found diphtheroid organisms present in a majority of the mouths he examined. While it was generally known to bacteriologists that many of the bacteria shown to be habitually present in the bacterial plaques were, under certain circumstances, acid-producers, Dr. Williams thought he might be able to offer more direct and extensive evidence. With the aid of Mr. R. F. Wood Smith he undertook the studies necessary to show whether the microorganisms found in the bacterial plaque were acid-producing. In this form of work rather long periods of time are required to permit definite conclusions because of the difficulty of isolating and culturing some of the organisms and the necessity for sufficient repetitions of each experiment to establish definite conclusions. At the presentation of this paper Dr. Williams was able to report definitely as to the acid-forming activities of only three of these organisms, as per the following table:

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[1] *The Dental Cosmos*, 1899, page 320.

	After 48 hours	After 3 days	After 7 days
Staphylococcus pyog. albus....	0.058	0.063	0.067
Staphylococcus pyog. aureus...	0.090	0.092	0.112
Sarcina lutea	0.000	0.000	0.031

Even this incomplete showing should have been conclusive, because all of the typal forms of oral microorganisms were found in the plaques, as may be seen in Figure 27[1]. Even these brief studies were important because Williams and Black concurred in the belief that the Staphylococcus organisms were probably present in practically all mouths.

He then isolated a very strongly growing mycelial (fungoid) organism which branched freely and developed robustly in forty-eight hours. This organism, which had apparently been unrecognized, is shown in Figure 27.

At the time of the presentation of this paper there were catalogued about one thousand species of bacteria. So minute were some of the differences in some of the forms catalogued separately that it had been suggested that the different forms might be, at least in many cases, merely different stages in the life cycles of a comparatively small number of organisms. One author, Plowright, instanced forty-seven fungi, different phases of one species, which had been classified as forty-seven species.

The appearance of different forms at different stages in the life history of a bacterium is known as "pleomorphism." It remained for Dr. Williams to offer new and revolutionary evidence on this subject which was of great importance to bacteriologists, medical men and dentists. Curiously enough, this discovery seems to have passed almost unnoticed, as far as the dental profession is concerned, and while many of Dr. Williams's presentations have entered so completely into the scientific thought of the profession that they are now

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[1] *The Dental Cosmos,* 1899, page 321.

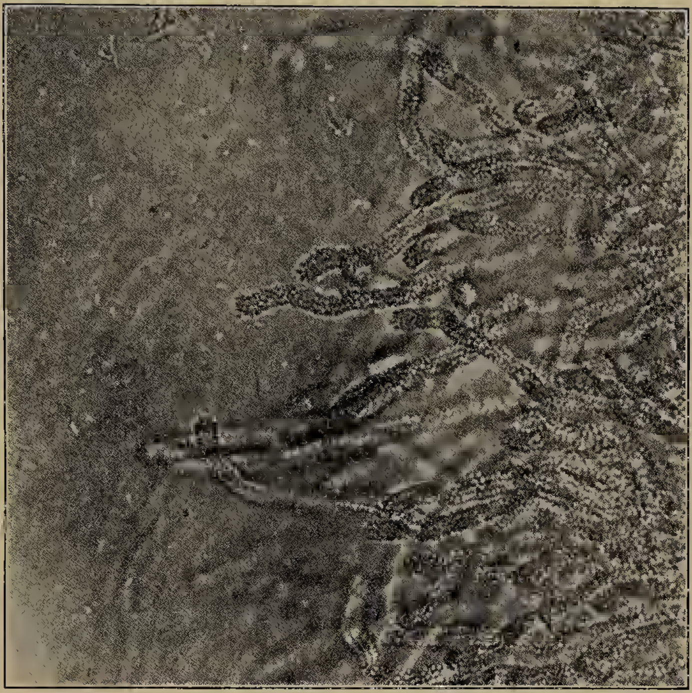

FIG. 30
Thick growth of Leptothrix racemosa fructification heads from approximal surface of tooth, under high magnifying power.

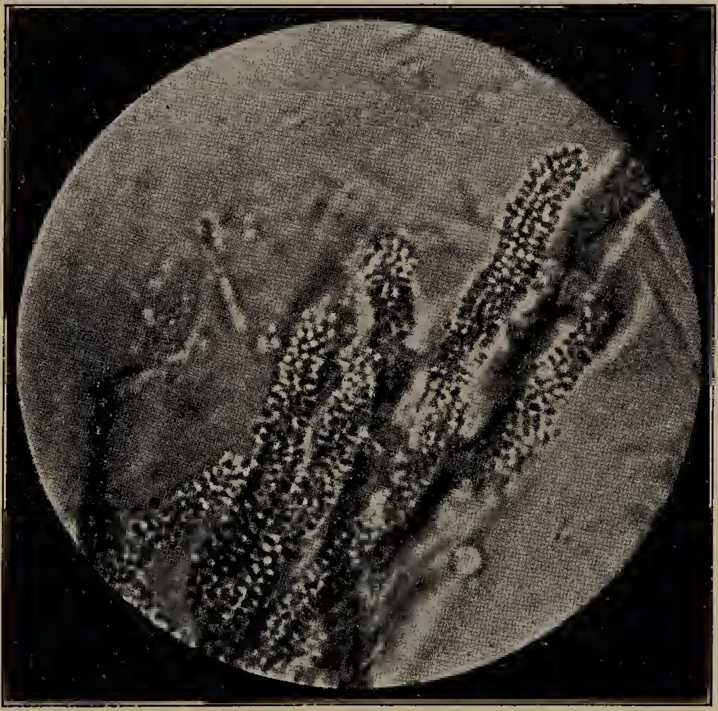

FIG. 31
Fructification heads of Leptothrix racemosa magnified 2000 diameters.

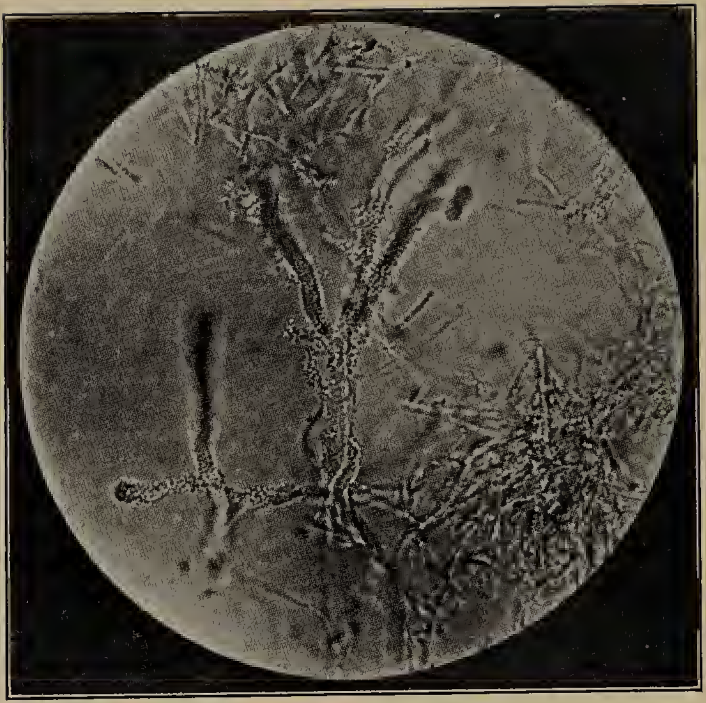

FIG. 32

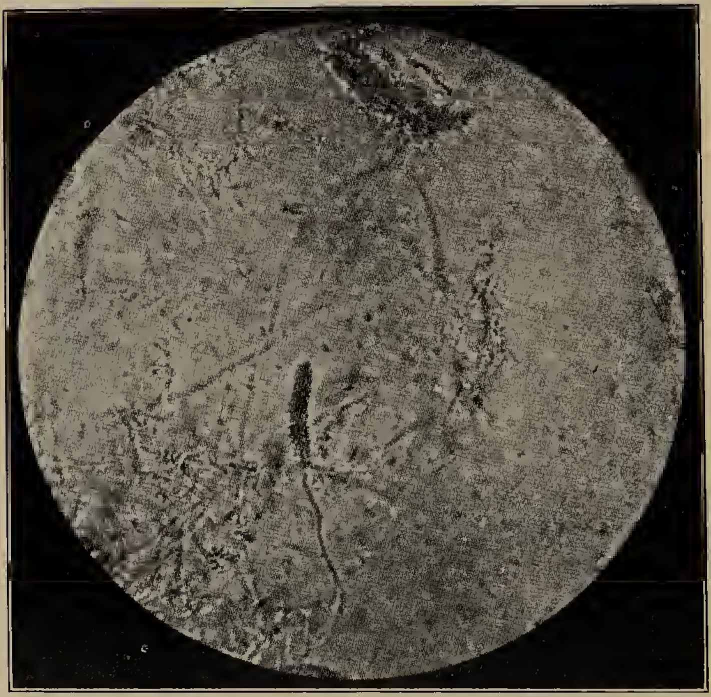

FIG. 33
At the top of the field in this view is seen a partially crushed head of Leptothrix racemosa, usually spoken of as a zooglea mass of micrococci.

part of its life, this one seems not to have affected the thought and teaching on this subject nearly so much as its importance would justify.

The Isolation of Leptothrix Racemosa

Dr. Williams was able to isolate a threadlike organism for which he could, at first, find no description. When stained in the usual way, that is, with one of the anilin dyes, it might easily be mistaken for Leptothrix buccalis. But an entirely different appearance was obtained by staining for eight or ten minutes in hot anilin-gentian-violet, fixing in hot iodid solution à la Gram, washing for two minutes in absolute alcohol followed by distilled water and counterstaining in methylene blue. The threads were seen to be composed of long and short segments or cells, and each segment contained a sporelike body. The terminal ends of the threads are often club-shaped, and these stain deeply. The organism sometimes branches, always at the sporelike bodies.

More than a year previous to the presentation of this paper Dr. Williams had been struck by the very regular arrangement of coccus forms about the ends of leptothrix threads but had regarded them as purely accidental. But the persistence and regularity of these forms in the preparations he was then making led him to examine them more closely. He was astounded to find what appeared to be a thornlike connection between the spore or coccus and the leptothrixlike thread. Through the assistance of a friend Dr. Williams learned that this organism had been observed and minutely described by Filandro Vicentini of Naples two or three years before. Vicentini's work was received by the scientific world in almost complete silence, due perhaps to the fact that he presented only drawings in support of his discovery and that he claimed too much for his parent organism.

The methods followed by Dr. Williams were somewhat different from those followed by Vicentini. Because these lessons from this work are but little understood, it may be worth while to summarize the technic briefly for the benefit of any who wish to undertake similar experiments.[1]

METHODS EMPLOYED IN ISOLATION

"A stream of sterilized water is thrown from a powerful syringe into the angle where two teeth meet, let us say between the first and second upper molars. With a sharp, sickle-shaped instrument, which has been sterilized, I remove a portion of the gelatinous microbic plaque, which may nearly always be found on the approximal surfaces of even fairly well-cared-for teeth. We shall find on our instrument a small mass of grayish-white material, which adheres to itself with considerable tenacity. This is placed in a clean watch-glass crystal and covered with twenty or thirty drops of a rather thin watery solution of methyl-violet-anilin water. The mass is allowed to remain in this solution for twelve hours, occasionally teasing it apart a little to allow the staining fluid to penetrate as much as possible. The staining fluid is then poured off, and the mass washed first with a few drops of sterilized water and then with a mixture of equal parts of glycerol, spirit and water. A drop of this same mixture is then placed on a cover glass, the stained mass put into it and teased apart as much as possible, and then carefully inverted on a slide, being very careful to make but little pressure at first upon the cover glass.

APPEARANCE OF LEPTOTHRIX RACEMOSA

"If the preparation is now examined under a one-quarter or a one-sixth-inch objective, fields will probably be somewhere found which resemble the photograph shown in Figure 28[2]. . . . Projecting from the edges of a mass of threadlike microorganisms, we shall see what at first appear to be very marked enlargements of the ends of some of the leptothrix forms. These enlarged ends vary greatly in length, although but little in diameter. Under a one-tenth or one-twelfth-inch objective we may, in fortu-

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[1] The following paragraphs are quoted from *The Dental Cosmos*, 1899, pages 335 to 348.

[2] *The Dental Cosmos*, 1899, page 327.

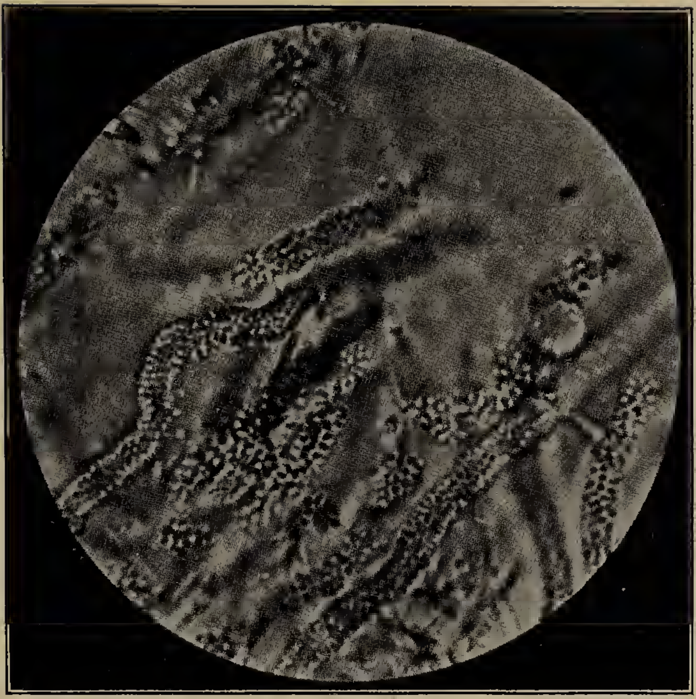

FIG. 34

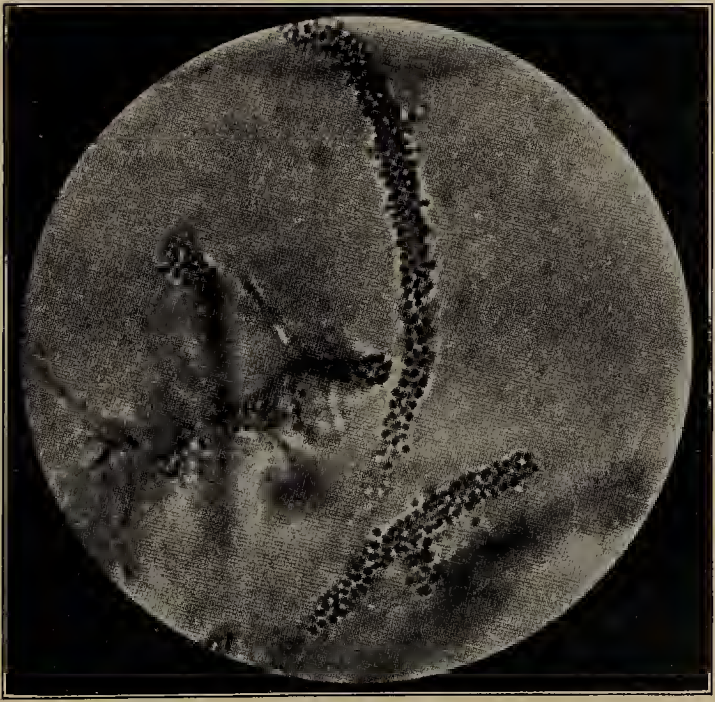

FIG. 35

There are appearances in this photograph and in several others shown in this paper which indicate that the spores of Leptothrix racemosa begin to multiply by fission while still attached to the parent stem.

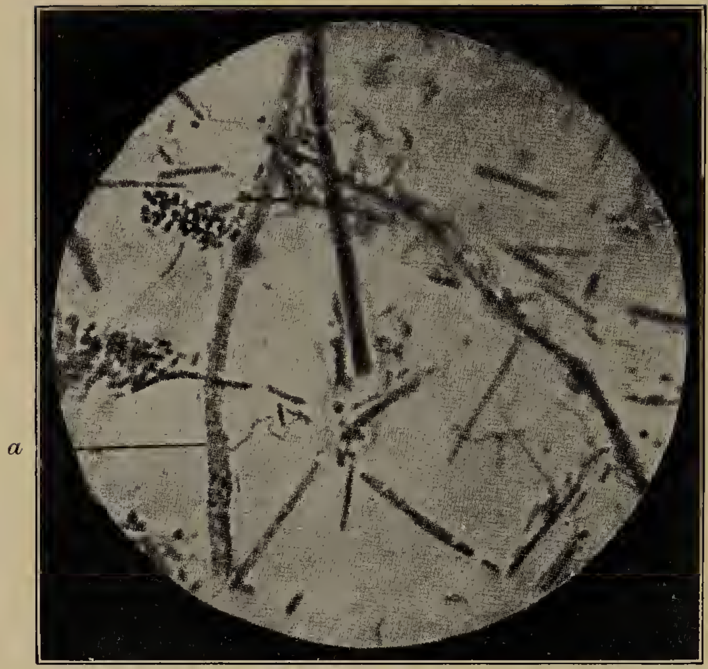

FIG. 36
Showing at *a* what Dr. Williams believes to be the enlarged end of thread or basidium, the first stage in the formation of the fructification head of Leptothrix racemosa. Balsam mount. Zeiss obj. 2 mm., proj. oc. 6.

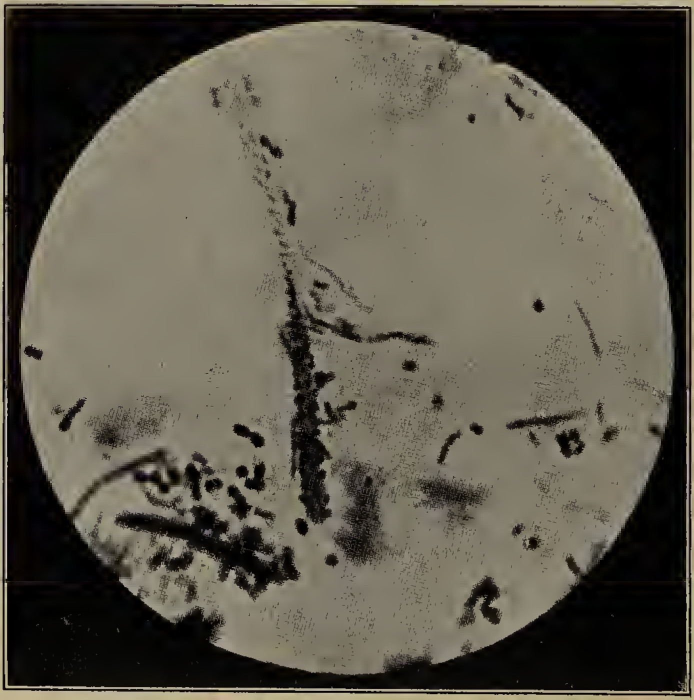

FIG. 37
Showing the budding of the basidium or fertile head of Leptothrix racemosa. Balsam mount. Zeiss obj. 2 mm., proj. oc. 6.

nate specimens, discover such fields as are shown in Figure 29[1]. Such views very closely resemble a grass plot, from which arise the blossom, fruit, or seed-heads of the plant. And this is really precisely what we are looking upon. These are the fruit or spore-heads of a threadlike microorganism which I have found to be as constant as any form of bacteria in the human mouth. As a matter of fact, I have not yet failed to find it in any mouth I have examined for it. This is the microorganism which Dr. Vicentini named Leptothrix racemosa, a name I shall provisionally accept because I am not yet certain that it is a leptothrix form. We see that these fruit or seed-heads of Leptothrix racemosa are made up of minute and generally regularly arranged rows. Dr. Vicentini says that there are always six rows. I have found by securing a few lucky views of cross or transverse sections of the heads that there are sometimes twelve rows or even more. Dr. Vicentini says that he was able to discover only the stems, thorns, sterigmata or peduncles which connect the spores to the parent stalk when he secured a very superior one-twenty-fifth-inch objective. But I have had no difficulty whatever in photographing them with my one-eighth or three mm. apochromat. Zeiss lens. . . . . In Figure 30[2], as seen under a high power, there are many places where the connection of the spores to the parent stem may be plainly seen. Generally when the spores first appear the sterigmata are very slender, but they subsequently enlarge until they produce, with the spore, a club-shaped organism indistinguishable, morphologically, from one of the forms of the bacillus of diphtheria. Such club-shaped spore formations are shown in several places in Figure 31[3], while the younger and very slender forms are seen in Figure 32[4]. A single short head is shown in Figure 33[5], while on the opposite side of the field is observed a crushed head, an appearance usually spoken of as a zooglea mass of micrococci. Seen under a power of about two thousand diameters, as in Figure 34[6], the spores are seen to vary considerably, both in shape and in size. While the majority are round or sphere-shaped, many are oval or ellipsoidal, and some few are curved. There are many appearances which indicate that the spores either begin to multiply by fission before they become separated from the parent stalk or are pushed outward by the formation of a secondary spore, which is formed from the same source as the first one, as shown in Figure 35[1].

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[1] *The Dental Cosmos,* 1899, page 328.
[2] *The Dental Cosmos,* 1899, page 331.
[3] *The Dental Cosmos,* 1899, page 332.
[4] *The Dental Cosmos,* 1899, page 333.
[5] *The Dental Cosmos,* 1899, page 334.
[6] *The Dental Cosmos,* 1899, page 335.

"There are known parallels for both methods in forms of fungi, the life history of which has been completely worked out, although we shall probably never be quite certain that this is true of Leptothrix racemosa unless we succeed in cultivating it, a feat of which, I am sorry to say, there is not much hope at present. Before proceeding to consider further the significance of these new facts let us examine some of the parallels, among the allied forms of life to which I have referred, for what seems at first sight like a very radical departure from all of our present views of the multiplication of bacteria. . . .

APPEARANCE OF THE GROWING FILAMENT

"This clublike enlargement of the growing end of the filament to which your attention is called is characteristic not only of the Hyphomycetes, but of all those species of micro-organisms which are conjectured to be degenerate forms of Hyphomycetes, such as the bacillus of diphtheria, of tuberculosis and of anthrax. It is also found in Cladothrix, Crenothrix and Beggiatoa, forms which are classed as bacteria, but which probably stand nearer the Hyphomycetes than do those which are parasites of the human organism. This clublike enlargement seems to be produced by increased activity and changes in the protoplasmic contents of the bacterial cell. It stains much more quickly and deeply than do other parts of the same fiber. But this activity of the cell protoplasm appears to be completely exhausted in the production of the spores, for soon after these begin to appear the rod stains feebly and slowly. There are strong indications that the commencement of the formation of the spores takes place within the protoplasm of the basidium, and that they grow out to complete their development externally. In Figure 36[1] we see a basidium containing many sporelike bodies which are still entirely within the cell wall. In Figure 37[2] we see another basidium in which these sporelike bodies are penetrating the cell wall and are already projecting somewhat beyond it, while in Figure 38[3], from a specimen mounted in glycerol, we observe the formation of the sterigmata well advanced, bearing these minute sporelike bodies upon their terminal points; and wherever we can look directly down upon these terminal points we see them deeply stained and corresponding exactly in appearance with the sporelike bodies seen at first within the cell protoplasm. I believe, therefore, that the fully formed spore represents a body the development of which, while completed externally to the cell, is begun within it. The formation of spores in Leptothrix racemosa generally, although not invariably, begins at the extreme tip of the fertile stalk and proceeds downward. Sometimes a few isolated spores may be seen standing on their fine peduncles or sterigmata at some little distance below the main head, and still below these one may see sporelike bodies within the cell. . . .

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[1] *The Dental Cosmos*, 1899, page 336.

"The attachment of the spores to the central stalk, which is really the final and irrefutable proof of the true fructification of this microorganism, is finely shown in Figure 39[4] . . . in both longitudinal and transverse sections. Figure 40[5] shows enlargements of the transverse sections to about nine thousand diameters. Some very interesting details of structure have been brought out in these high magnifications. . . .

REVIEW OF THE STAGES OF FRUCTIFICATION

"Reviewing the various stages of the fructification of Leptothrix racemosa which are illustrated in the accompanying photographs, we see first a club-shaped enlargement of the outer ends of the fertile fibers, which stains more quickly and deeply than the rest of the fiber. The next stage, apparently, is the segregation of the protoplasm in the enlarged end into sporelike bodies, but which differ from spores in staining more easily. Next, a slight bulging or protuberance of the cell wall directly over each sporelike body is observed, followed by various stages of the sprouting of the sterigmata and the formation and full development of the spores upon their terminal points. A great majority of the spores are coccus-shaped, but some of them are oval, and they vary considerably in size. Some of the spore bodies apparently begin to multiply by fission before they are detached from the parent stem. These, when separated from the stem, would have the morphological appearance of diplococci. When single spores with their sterigmata are detached they have the form of the club-shaped diphtheroid bacillus, and sometimes of a curved bacillus. Leptothrix racemosa is common to all mouths which I have examined. The forms which must result from the breaking up of the spore-heads and stems of this microorganism are long and short rods, various sizes of micrococci, various sizes of diplococci, and various sizes of curved and club-shaped bacilli.

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[1] *The Dental Cosmos,* 1899, page 339.
[2] *The Dental Cosmos,* 1899, page 340.
[3] *The Dental Cosmos,* 1899, page 341.
[4] *The Dental Cosmos,* 1899, page 345.
[5] *The Dental Cosmos,* 1899, page 346.

THE PRODUCTION OF NUMBERLESS MICROORGANISMS

"I have no disposition to indulge in speculation over these discoveries, but here are the facts which must be reckoned with in all future considerations of the bacteria of the human mouth and body. It would be folly to deny that these facts are big with possibilities. After the most thorough cleansing of my own mouth by the aid of toothbrush, pick, silk floss and powerful germicides I have, after forty-eight hours, found the fructification heads of Leptothrix racemosa growing luxuriantly. They must therefore develop with considerable rapidity. However much we may be disposed to reticence, it is impossible to avoid asking what becomes of the enormous number of microorganisms of different forms and sizes which are being constantly shed into the mouth by this parent organism, and how many of them have been classified as permanent species.

"It now becomes perfectly plain why such a large number of different forms are found in the microbic plaques

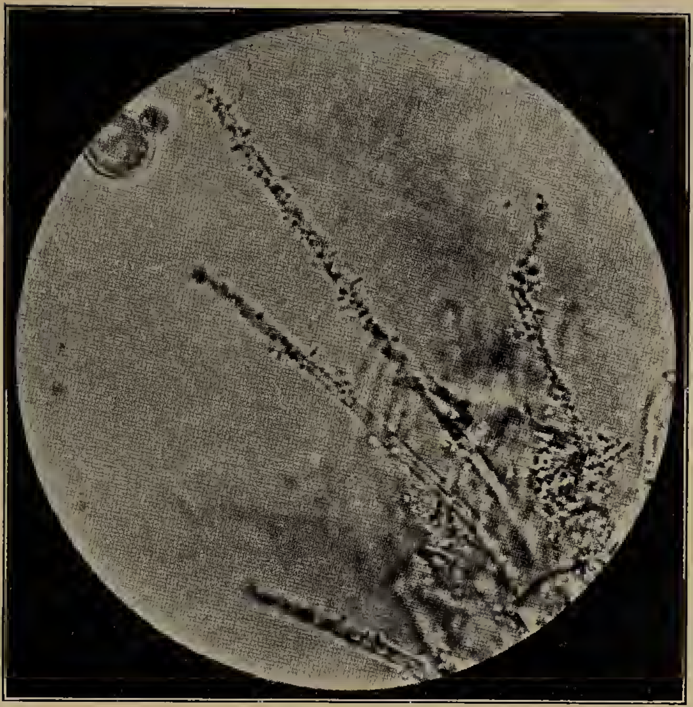

FIG. 38
Budding of heads of fertile threads of Leptothrix racemosa. Glycerol mount. Zeiss obj. 2 mm., proj. oc. 6.

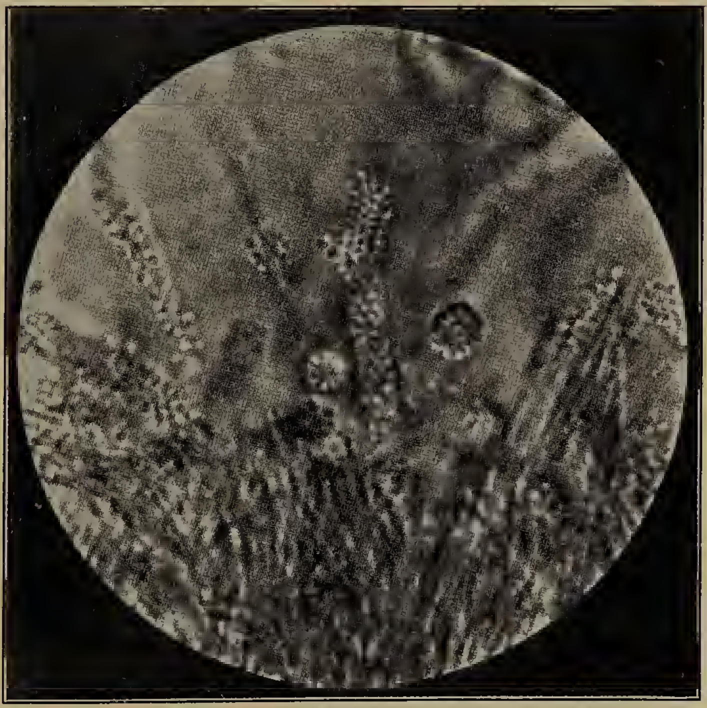

FIG. 39
Showing attachment of spores to central stem in both longitudinal and transverse sections.

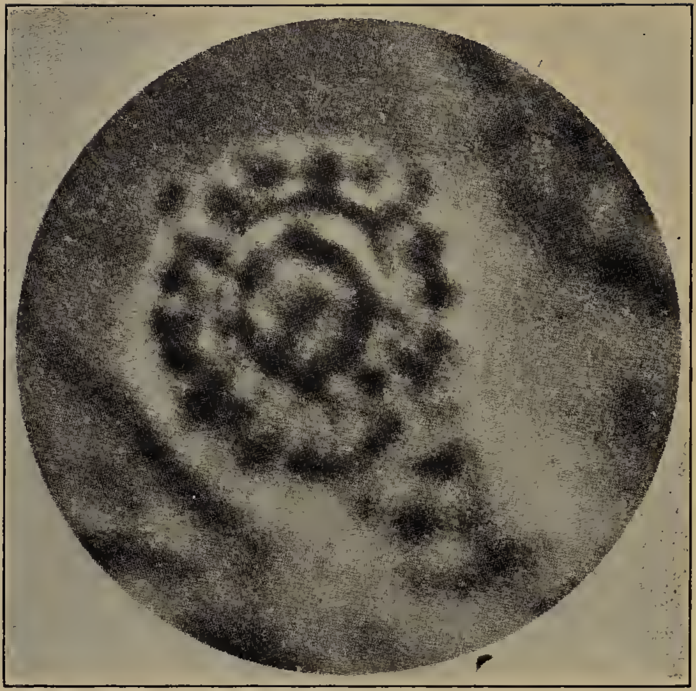

FIG. 40
From enlarged negative made from original photograph of transverse section of fructification head of Leptothrix racemosa. Original negative was magnified to 2000 diameters. Enlarged negative and print above represent amplification of about 9000 diameters. It shows cell wall and shrinkage of protoplasm caused by action of glycerol and spirit. Spore-stems or sterigmata are seen to arise from central protoplasm and to pass through cell wall.

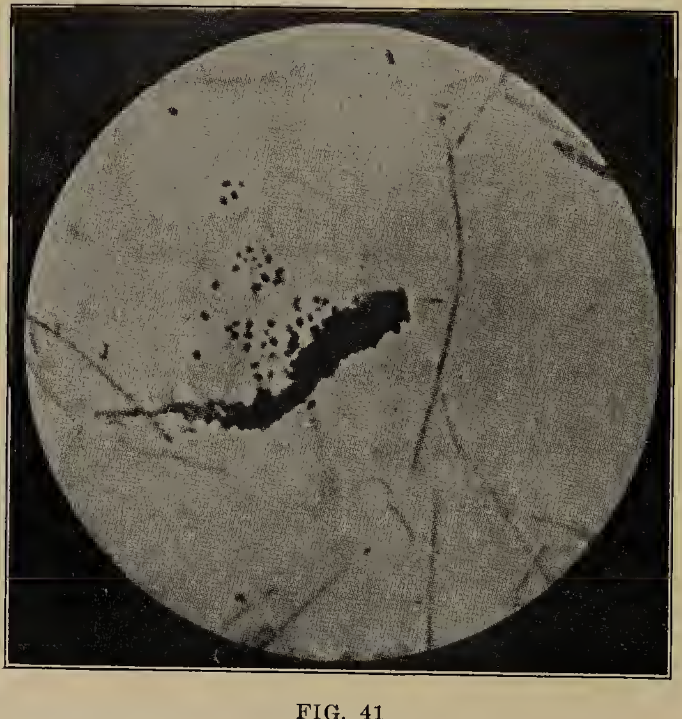

FIG. 41
Fructification head mounted in balsam and showing detachment of spores.

which Dr. Truman supposed to be chiefly or entirely composed of Leptothrix buccalis. A large majority of these forms are undoubtedly the product of Leptothrix racemosa. The zooglea masses of micrococci so frequently met with in these microbic plaques are probably entirely composed of the spores, generally the crushed spore-heads, of our new organism. In Figure 41[1] a spore-head is shown with a bare place where some of the spores have evidently been brushed off and are scattered about in the vicinity. The most conservative and skeptical observer could, I think, have no hesitation in admitting that the scattered spores of various sizes and shapes came from the partially destroyed head."

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[1] *The Dental Cosmos,* 1899, page 347.

CHAPTER XII

"DISPUTED POINTS AND UNSOLVED PROBLEMS IN THE NORMAL AND PATHOLOGICAL HISTOLOGY OF ENAMEL"[1]

AT the time of the delivery of the address which bore the title given above there was a division of opinion in the profession as to whether or not chemical and metabolic changes occur in the enamel of erupted teeth. More than twenty years ago Dr. Williams expressed the opinion that enamel contained no organic matter and that therefore there could be no organic changes in that tissue. That opinion, which was based largely on the failure of efforts to stain enamel, was supported by Dr. Black, Sir Charles Tomes and Professor Hopewell-Smith. Recently several investigators have announced success in their efforts to stain enamel.

The opinion, based on clinical evidence, that there take place in enamel changes which must be due to chemical and metabolic actions was strengthened by the work of Professor Pickerill. If it could be shown that metabolic and chemical changes take place in the enamel of erupted teeth, it might be possible to learn to control those changes in such way as to improve the quality of the enamel and its power to resist decay. Dr. Williams stated that he had long been studying this question and was hopeful that such a conclusion would be reached. This presentation was devoted to clearing up some long-standing questions that bore upon the main problems.

THE STRUCTURE OF MARSUPIAL ENAMEL[2]

Dr. Williams then called attention to the structure of marsupial enamel. "It often happens that much is learned

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[1] As President of the International Society for Dental Research, Dr. Williams delivered before that Society an address dealing, in extenso, with the subjects mentioned in this title, on January 27, 1922. Space here permits only brief summaries of the more important points. The complete address will be published in *The Journal of Dental Research.*

[2] The marsupials are the animals that carry their young in pouches.

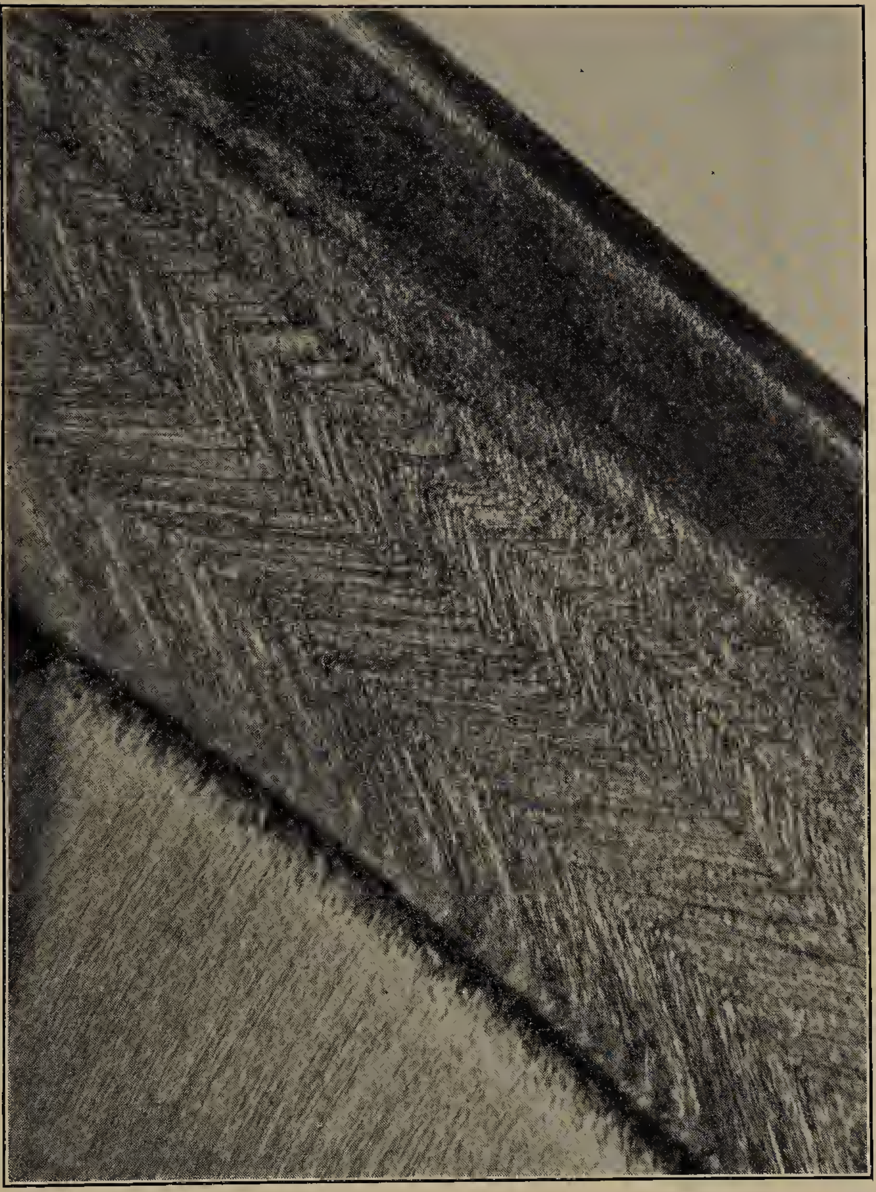

FIG. 42

Section of incisor of large grey kangaroo. It should be kept in mind that a section represents but a *single* plane while the real form-arrangement is in *three* planes. The spiral represents the typal course of enamel rods in human teeth and in teeth of most animals. Sections of enamel must be ground at many angles in order to comprehend the ultimate arrangement of the rods.

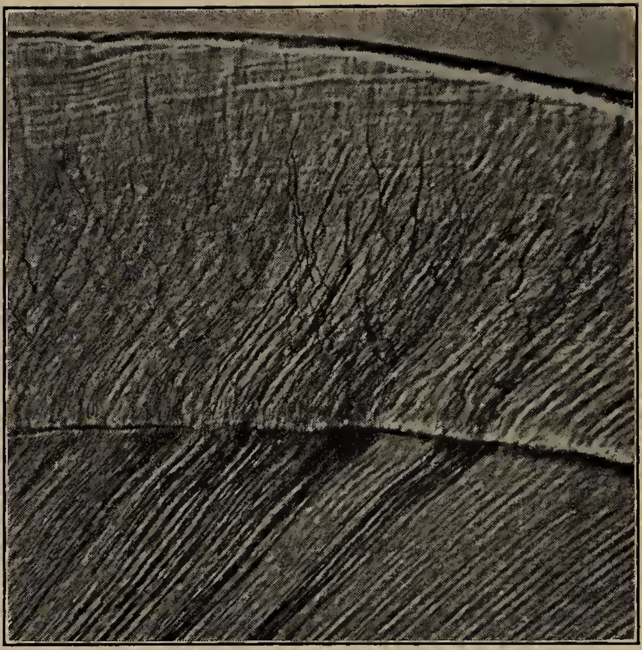

FIG. 43

Section of lower premolar of opossum, the only American marsupial. Nearly all marsupials have organic fibers in enamel, origin of which has long been a subject of controversy. This shows clearly that fibers in enamel are prolongations of dentinal fibers.

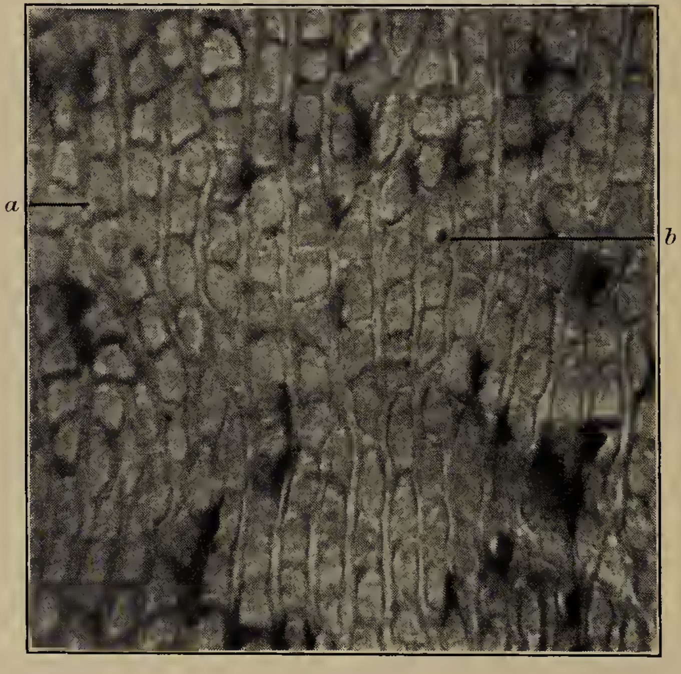

FIG. 44

Cross or transverse section of Fig. 42 stained with nitrate of silver solution. Shows that organic fibers are mostly arranged in groups and their position is nearly always in cement-substance between enamel rods. A few, however, as at *a* and *b*, are in enamel rods. These penetrate enamel during early stages of formative period before calcification begins.

about the structure and function of human tissues by the study of structure and function of corresponding parts in lower animals. It has long been known that there is considerable organic material in the shape of uncalcified fibers in marsupial enamel." Tomes believed that in marsupial enamel the calcification of the enamel rods began at the periphery and proceeded toward the center. Sometimes the rod completely calcified, in which case it was solid. When it did not completely calcify, it left a small fiber as an uncalcified center. If it could be demonstrated that human enamel is formed in the way Tomes believed marsupial enamel is formed and that uncalcified fibers remain in the rods, we should be justified in assuming that organic changes take place in human enamel.

Opposite Deductions by Tomes and Mummery

In 1905 Dr. Williams showed Tomes some photographs of transverse sections of the enamel of the kangaroo in which many of the fibers were clearly seen. Tomes drew the deduction that three-quarters of the tubes appear in the rods and one-quarter in the cement-substance between the rods.[1] Mr. J. Howard Mummery saw the photographs which were shown to Tomes and later made a careful investigation of the subject. His conclusion—that an occasional tube or fiber may appear to be in the rods and that this appearance may probably be explained as due to the thickness of the section—is exactly opposite to the conclusion reached by Tomes. Paul and Von Ebner agree with Mummery that the enamel fibers are in the cement-substance. The difference of opinion between such authorities of the highest rank in this field is probably due to the preparation of specimens in balsam, which, as Dr. Williams pointed out long ago, is about the poorest method of preparing specimens for study of the histology of the dental tissues. It is exceedingly difficult to get a good, well-stained specimen of marsupial enamel because many abrupt changes in the direction of the enamel rods make a cross section of these rods a very elusive thing.

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[1] *Manual of Dental Anatomy,* seventh edition.

Do Fibers Originate in the Enamel?

Dr. Williams then called attention to two distinct phases of this problem:

a. Are the enamel fibers in marsupial enamel a strictly enamel production, as claimed by Tomes, or do they have their origin in the dentine, as Dr. Williams had suggested more than twenty-five years before?

b. Do these fibers pass in the rods or in the cement-substance, or both?

The fact that, in many instances, there is a distinct enlargement of these fibers at the dento-enamel junction gave considerable color to Tomes's claim that the connection of the enamel fibers with the dentinal fibers at the dento-enamel border is in the nature of an anastomosis. In many instances this enlargement does not appear and the fibers pass, without change of direction or size, from the dentine into the enamel.

The final proof that in marsupial enamel the enamel fibers are continuations of the dentinal fibers came in a fortunate ground specimen from an opossum. In Figure 43 the dentinal fibers are seen in groups, some dark, some light. The groups which appear dark in the dentine continue straight on into the enamel. This is true of all the groups and of all the fibers. We may therefore conclude that the enamel fibers in the marsupial enamel are prolongations of the dentinal fibers.

Most Enamel Fibers in Cement-Substance

Let us now examine the position of the fibers in their relation to the enamel rods. Figure 44 is from a transverse section of enamel from an upper incisor of a kangaroo, seen under high power. Some of the rods are shown in exact transverse section and others are cut more obliquely. The organic fibers are deeply stained and show plainly on the unstainable background of the enamel. In all of the many specimens Dr. Williams examined he found the fibers in the center of the enamel rods in only two or three instances. In a small percentage of cases the fibers occupy varying positions in the rods, mostly at one side. At least 90 per cent of the fibers are in the cement-substance between the rods.

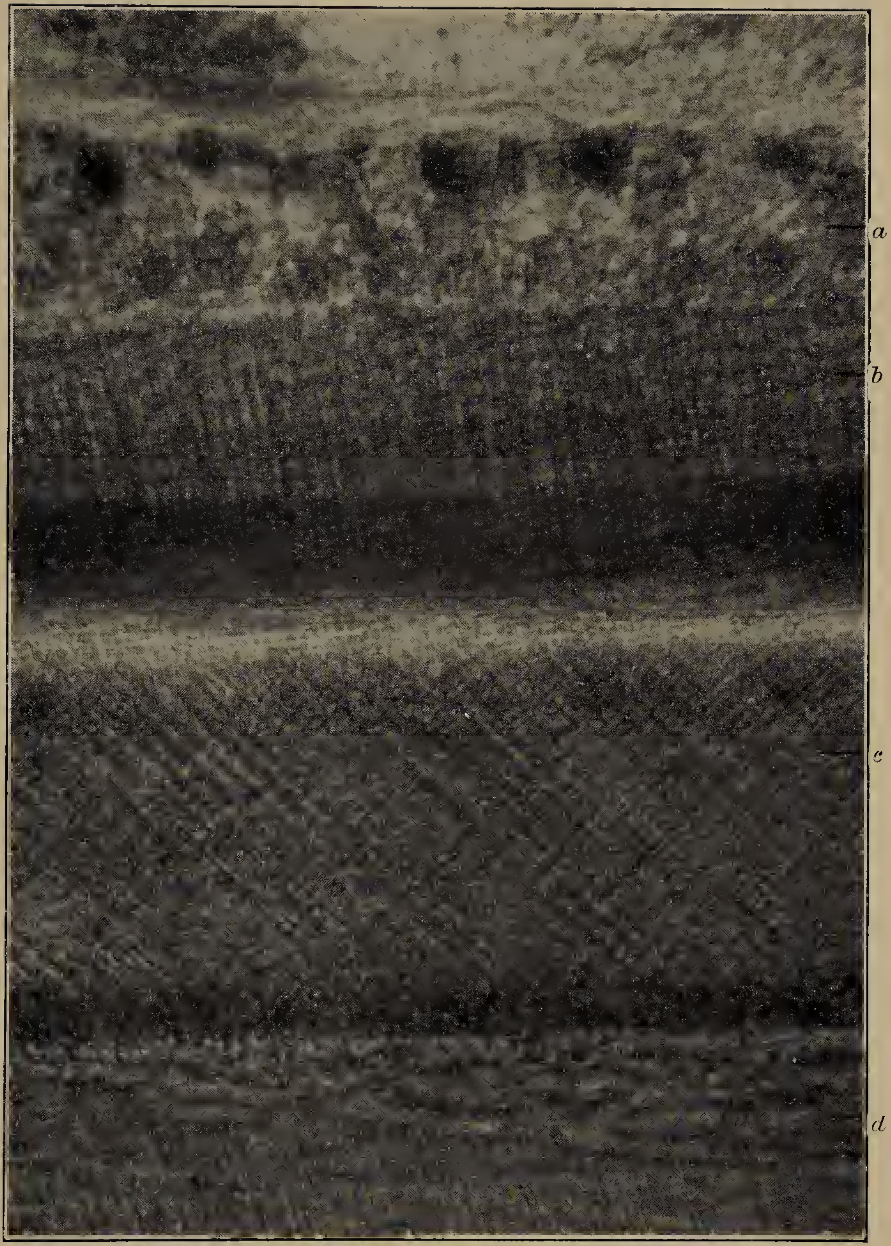

FIG. 45
Formation of enamel in persistently growing incisor of albino rat. The cells of the stratum intermedium, *a*, have been converted into a secreting organ with many papillæ arranged around blood vessels (shown dark in cross section). Staining was effected by injection of Trypan blue into abdominal cavity. All tissues except fully formed enamel are stained. *b*—Ameloblasts. *c*—Enamel. *d*—Dentine.

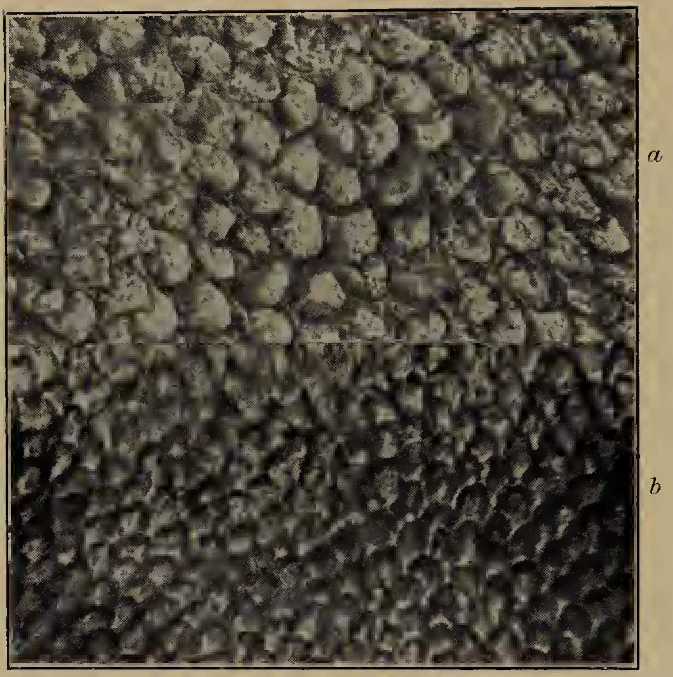

FIG. 46

Cross section of enamel from human molar tooth. a—Near surface of tooth. b—Near dento-enamel junction. Diameter of enamel rods near surface is nearly twice as great as at dento-enamel junction. The theory that the larger surface area is provided for by branching of rods is thus shown to be incorrect.

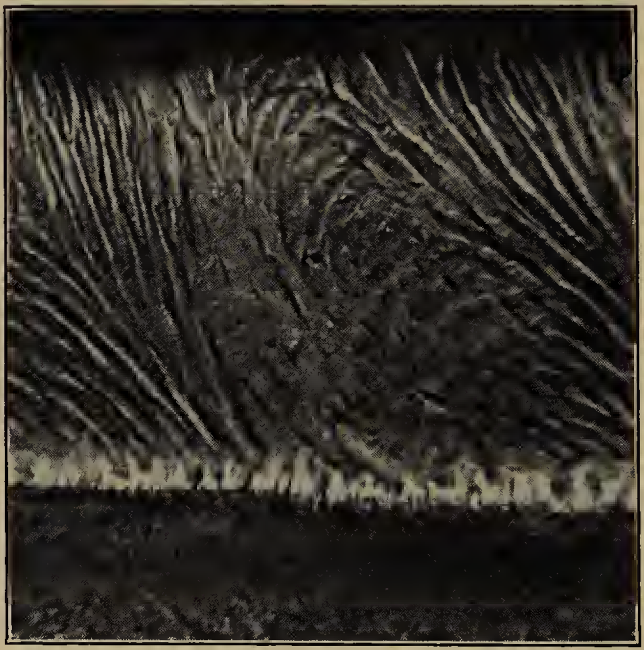

FIG. 47

Section of enamel from incisor of Belgian hare. Shows a certain modification of spiral arrangement of enamel rods. The contention that spiral arrangement of rods in human enamel represents abnormal or imperfect formation is seen to have no foundation in fact. This arrangement is most characteristic feature in nearly all forms of enamel and adds greatly to its power of resistance to pressure.

A few of the fibers divide in the enamel, and a few abruptly change direction without reference to the direction of the enamel rods (Figure 43). The function of these organic fibers in marsupial enamel is still a mystery.

WHAT IS THE ENAMEL ORGAN?

When the germ of a human tooth is completely encapsuled, the enamel organ consists of the following parts:

> The ameloblasts, the cells which give form to the enamel rods.
>
> The stratum intermedium, two or three layers of round or oval cells at the outer ends of the ameloblasts.
>
> The stellate reticulum, which, in the early stages of the tooth germ, occupies much the larger part of the tooth sac but which rapidly decreases in size and, in many instances, disappears long before the formation of enamel is completed.

In 1895 Dr. Williams presented evidence that the enamel organ of the rodents contains no stellate reticulum and that there is developed in place of the stellate reticulum, from the outer and inner layers of columnar cells, a true secreting organ and he inferred that in the human and other animal species the corresponding cells perform precisely the same function.

MISREPRESENTATION BY JORDAN AND TOMES

This evidence and this inference have been misunderstood and misrepresented, notably by Dr. H. E. Jordan[1] and Sir Charles Tomes[2]. Dr. Jordan thoroughly misunderstood Dr. Williams's evidence to the effect that the formation of the secreting organ for the production of enamel begins in the outer epithelial layer and when the outer epithelial layer and the stratum intermedium come together, after the disappearance of the stellate reticulum, continued development of the papilliform layer takes place.

Dr. Williams said that it seemed to him that Tomes made the mistake of thinking that glandular function occurs only when there is a papilliform arrangement of the cells, whereas he long ago showed that the cells of the stratum intermedium perform a glandular function before the disappearance of the stellate reticulum and the formation in the stratum intermedium of the papilliform structure.

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[1] In *The American Journal of Anatomy,* September, 1921.

[2] *Manual of Dental Anatomy,* seventh edition.

Secretion is that process by which the body cells separate materials from the blood which they build into new substances. After the disappearance of the stellate reticulum and the formation of the papilliform layer in the stratum intermedium the material for the development of the enamel passes through these cells before it reaches the ameloblasts. These cells therefore perform the function of secretion.

In the rodents, in which the enamel is considered to be of the highest order of perfection, new enamel is constantly being formed. Dr. John H. Marshall said that in the albino rat the entire length of the lower incisors changes every thirteen or fourteen weeks. In none of the persistently growing incisors and molars of these animals is there any trace of a stellate reticulum or of a joining of the outer or inner epithelial layer to form the enamel organ. The enamel organ is developed as a secreting organ, in situ, from the beginning. Dr. Williams has proved this to be the case with the beaver, porcupine, woodchuck, muskrat and several varieties of squirrel.

As previously mentioned, the statement that Dr. Williams made nearly thirty years ago that the enamel organ is a true secreting organ had to wait more than twenty years before the studies by J. H. Mummery confirmed it. A very strong confirmation of the views that the ameloblasts give form and character to the enamel rods and that, so far as we know, this is their sole function is found in the fact pointed out by Tomes and Mummery that in certain fishes, after a thin layer of enamel is deposited, the ameloblasts disappear but the formation of the enamel goes on. Probably this enamel is always structureless. No appearance of the enamel rods can be discovered because there are no ameloblasts there to give form to the enamel rods.

The Formation of Nasmyth's Membrane

The formation of Nasmyth's membrane, which is, so to speak, the last act in the development of the enamel, is most clearly seen in the persistently growing teeth of the rodents. In a thin section from an incisor of a rat the ameloblasts were about the same length over the inner or formative half of the tooth. From about midway in the length of a tooth to the point of eruption the ameloblasts greatly decreased in length and changed from their normal position at about right angles to the long axis of the tooth, so that, in the outer half of the tooth, they assumed a reclining position and, just before the tooth emerged from the jaw, they lay flat upon the surface of the enamel. Up to the point of eruption the nuclei stained perfectly, so that the position of each cell was clearly seen. The papillary layer continued its form and apparently its function very nearly up to the time when the tooth emerged from the jaw.

ARE THE ENAMEL RODS OF THE SAME DIAMETER THROUGHOUT AS CLAIMED BY NOYES OR DO THEY DIVIDE AND BRANCH AS DESCRIBED BY MUMMERY?

The outer enamel surface of most teeth is nearly twice as great in area as the enamel at the dento-enamel junction. How does this increase in area come about? Noyes stated that the enamel rods are of the same diameter throughout. Mummery thought that in the enamel of the wart hog the rods branch as they pass toward the surface of the teeth. Dr. Williams believes this appearance of branching is always due to the tortuous course of the rods. Enamel rods often pass between other rods and so give the appearance of branching. Mummery's photograph shows quite as many rods branching toward the dentine as away from it. The enamel rods are not of the same diameter throughout. On the average the ratio of the diameter at the dento-enamel border to the diameter of the surface is as 5.5 to 10. Pickerill's measurements do not greatly differ from Dr. Williams's.

LINES OF RETZIUS

These lines are caused by the constrictions between the varicosities of the enamel rods. They represent the rhythmic action of the enamel organ in the deposit of the globular secretions of which the enamel rods are formed. When this action of the enamel organ is perfect, a row of these globular bodies is deposited, simultaneously, around the entire circumference of the developing enamel cap. This row marks a developmental line completely around the tooth, when observed in transverse section. When seen in longitudinal section, the lines run obliquely from the dento-enamel border to the surface.

Marked fluctuations of the vital activities of the mother during the development of a tooth cause molecular disturbance in the forming enamel which changes the action of the light waves in reflected and transmitted light. There is also, in some instances, slight pigmentation of a number of these rhythmic deposits, giving the effect of a colored band of greater or less width composed of the lines that have been described.

The Schreger bands are a purely structural phenomenon and present one modification of the spiral, which is a fundamental form-arrangement of the rods in nearly all varieties of enamel.

To all who are familiar with the conventionally cut sections of enamel—mostly straight, longitudinal sections—the real structure of this tissue, especially in the rodents, as revealed in sections cut at a variety of angles, may be something in the nature of a surprise.

In the enamel of the beaver, for instance, bundles of a dozen or a score of enamel rods are twisted into the form of rope, and these ropelike bundles are arranged into forms resembling woven fabrics. These complicated form-arrangements are admirably adapted to meet the stress to which the teeth of the rodent are subjected. Running through all the varied form-arrangements of the enamel rods, in all animals, we see modifications of that arrangement which, in human teeth, is known as the "Schreger bands."

Degenerative Changes in the Enamel of Guinea-Pigs as a Result of Excluding Vitamines from the Diet

Dr. Williams then spoke of his interest in and admiration for the important work Dr. Percy R. Howe is doing in demonstrating the effects of diet upon the conditions of

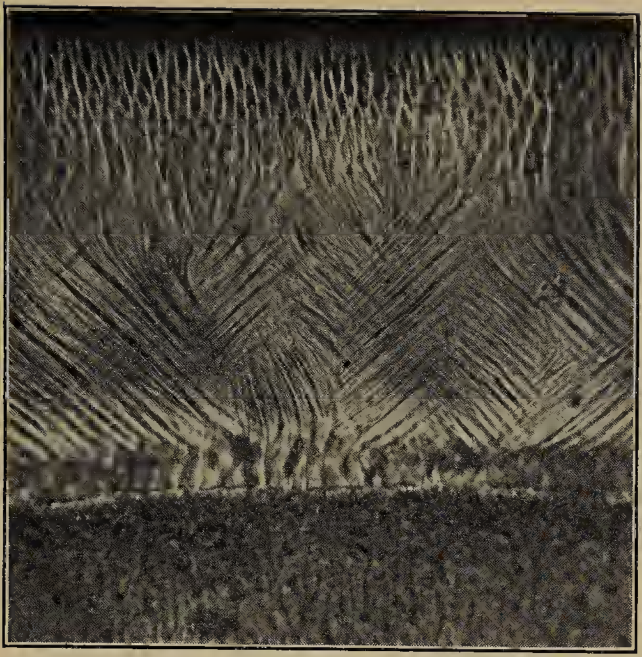

FIG. 48
Oblique section of enamel from lower incisor of muskrat. Another modification of spiral is seen in course of rods in inner portion of enamel. In outer part rods are cut almost transversely.

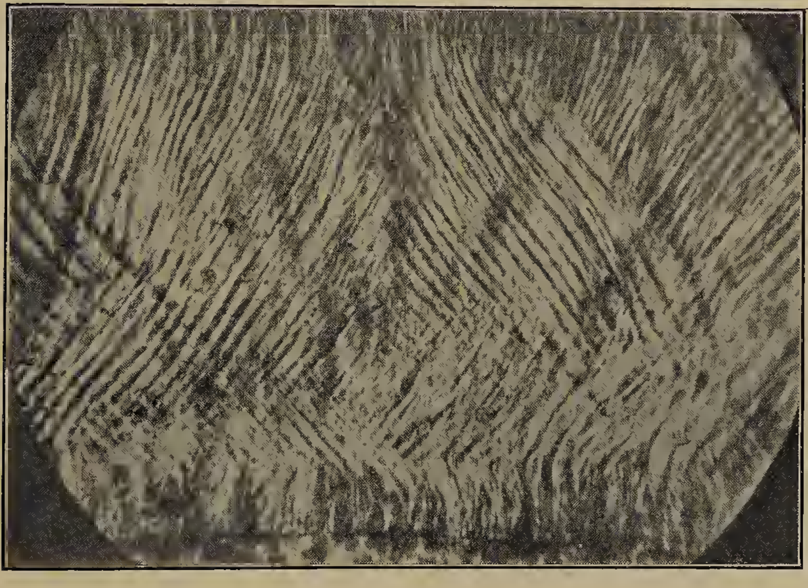

FIG. 49
One aspect of arrangement of enamel rods in incisor of beaver. Rod arrangement in enamel of beaver is most complex of any studied by Dr. Williams. This complex structure gives the great strength necessary to the use which beaver makes of incisor teeth.

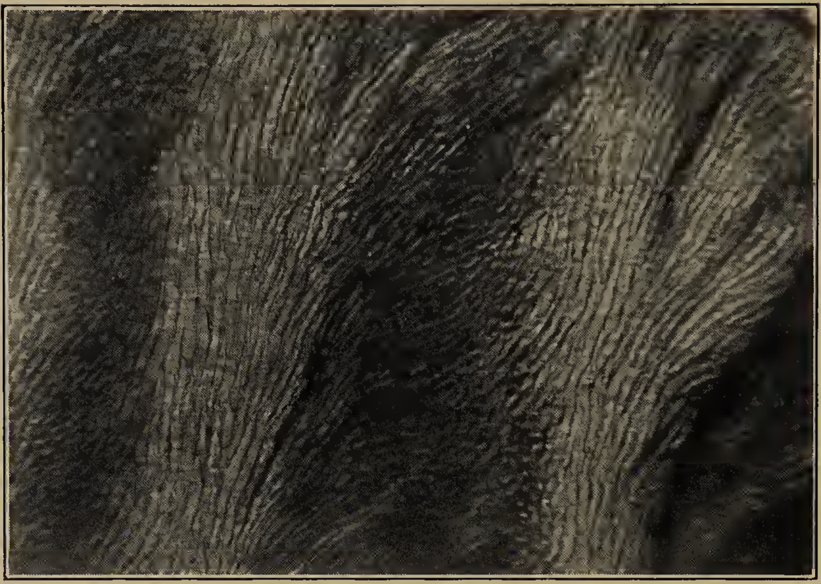

FIG. 50

Section from human tooth. Shows that the appearance of so-called Schreger bands is due entirely to spiral form-arrangement of enamel rods.

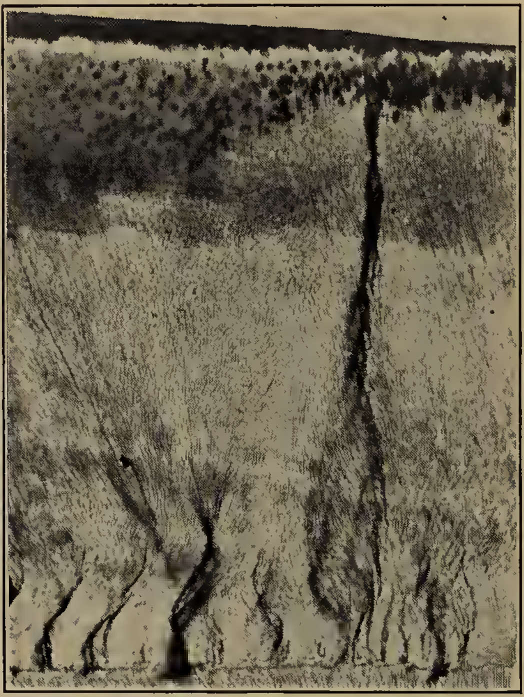

FIG. 51

Section from human tooth showing early stages of caries of enamel, cut somewhat obliquely to course of enamel rods and stained with nitrate of silver solution. Black spots in upper part show manner in which acid of caries penetrates enamel beneath bacterial plaque. Also shows spiral arrangement of enamel rods and that stain entering enamel from dentine always penetrates center of spiral first and then spreads out, following course of rods.

health and disease in the teeth. Dr. Howe has been able to produce profound disturbances in the two functions of the enamel organ, that of forming enamel rods and that of secreting calcific material in guinea-pigs which he has fed upon a vitamine-free diet. Dr. Williams does not believe these results to be entirely applicable to human enamel because in guinea-pigs the enamel organ is present and acting during the time of feeding, while in human enamel the organ is lost before controlled feeding becomes possible. Dr. Williams then asked the question: "Can true metabolic changes take place in a tissue after the formative cells have disappeared?"

New Proof of the Part the Bacterial Plaque Plays in Decaying Enamel

Pickerill and others do not believe that decay of human enamel is caused by acid-forming microorganisms in the bacterial plaque, as demonstrated by Dr. Williams in 1897. They base their doubts upon the fact that bacterial plaques are found on all surfaces of all teeth in persons immune to caries as well as in persons susceptible to it, in animals and even in human beings where decay has been arrested by natural causes.

They believe that decay arises from the presence of microorganisms in the mouth in general rather than in the plaques and from the lodgment of carbohydrate material and that the circumstances which favor the formation of the plaques also favor the lodgment of the carbohydrate material.

Dr. Williams agreed that the plaques are found on all surfaces of all teeth in persons immune to decay and in the mouths of animals. He agreed that decay does not occur beneath all plaques, probably because the majority or all of the organisms in some plaques may not be acid-producing or because some substance or condition confers immunity on the individual. The matlike substance of the plaques soaks up the carbohydrate material and holds it where the acid-forming bacteria, when present, can act upon it and protect the organisms while they deliver the dissolving substance upon the enamel. He concluded this part of the subject by saying that he had presented ample evidence of the dissolving action on enamel of the substances beneath the bacterial plaques and that in all the experiments he had made he had never seen such an appearance in dissolving enamel when the plaque was not present.

Possible Influence of the Endocrine Glands

Dr. Williams concluded this paper by calling attention to the fact that he had reviewed three pathological conditions of enamel: the result of vitamine-free food, the result of inherited syphilis and the dissolution of the enamel beneath bacterial plaques. "Are these conditions in any way related? Is there any condition of any part of the organism common to all these pathological changes? There is a considerable and steadily increasing body of evidence that certain disturbances of the endocrine balance produce decided effects in calcium metabolism." Professor Cobb has reached the conclusion that dental caries is one result of thyroid and parathyroid deficiency. McCollum believes that calcium metabolism is controlled by these glands. Professor Lewis Berman says that a conspicuous consequence of the removal of the parathyroids is a failure of the teeth to develop, particularly the enamel.

* * *

Here is a subject of the deepest interest to dentistry awaiting further investigation. What will the profession do to encourage research work in this field?

CHAPTER XIII

"MOTTLED ENAMEL—AND OTHER STUDIES OF NORMAL AND PATHOLOGICAL CONDITIONS OF THIS TISSUE"

ON December 5, 1922, a signal honor was conferred upon Dr. Williams by the Ohio State Dental Society at its annual meeting in Cincinnati. On that occasion he was presented with the first Callahan Medal ever awarded. This medal is a memorial established in the name of John R. Callahan, D.D.S., as "a tribute from his colleagues in recognition of his achievements in the field of root canal therapy,"[1] and it was bestowed upon Dr. Williams "in recognition of the high merit of the scientific contributions which he has made to humanity and the healing professions."[1]

Dr. Weston A. Price of Cleveland, Chairman of the Callahan Memorial Award Commission, in presenting the medal, spoke, in part, as follows:

"In the selection of the man who has been your essayist today we naturally thought of the men who have builded widely and strongly into the great commercial phases of dentistry. And then we thought of those who had built into the anatomy, histology and physiology, and we looked farther and thought we could see in the life of one man one who had built for anatomy, one who had built for histology, and, best of all, one who had built for the elevation of the standards of our profession. And somehow, as we think of this man, we cannot separate him from all three of these great activities. . . .

"I see in this man, Dr. Williams, a true servant of our profession, not only one who has devoted himself to this search for the truth, for the establishing of the foundations of life, but also one who says that science is ultimately to give us the interpretation of God and religion. . . .

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[1] Quoted from the medal.

"As we come to this moment of expressing in a most feeble way to Dr. Williams our gratitude and our esteem for the work he is doing, this little token we shall hand him is the simplest part of all our love."

* * *

It was in connection with the presentation of the Callahan Medal that Dr. Williams delivered the paper entitled *Mottled Enamel—and Other Studies of Normal and Pathological Conditions of This Tissue,* extracts from which are given in this chapter.[1]

MOTTLED ENAMEL

"About three years ago I began a reinvestigation of the field of enamel formation and structure which I covered some twenty-eight years ago. I was led to do this because of the statements of Pickerill and others as to the permeability of enamel and differing degrees of consolidation and hardness of this tissue as shown in different teeth. This new investigation has resulted in two things: a confirmation of most of the views which I had published on the formation of enamel and a considerable modification of my former opinions as to the structure and nature of fully formed enamel. I had formerly agreed with Black, Hopewell-Smith and others that normal human enamel was impermeable to stains and that no reconstructive changes could take place in enamel after the eruption of the teeth. The evidence now available makes such a position entirely untenable. . . .

"In what was, I believe, the last paper written by Dr. G. V. Black, in collaboration with Dr. Frederick S. McKay, on *Mottled Enamel,* he said: 'We cannot stain the body of normal enamel with any staining agent we know.' I had said the same thing many years before. Then, later, came statements from a number of competent observers, notably Mr. J. Howard Mummery of London, Dr. C. F. W. Bodecker of Berlin, Caush, Von Ebner, Fleischmann, Von Beust, and later Professor Russell W. Bunting and others.

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[1] The entire paper, profusely illustrated, will appear in an early issue of *The Journal of Dental Research.*

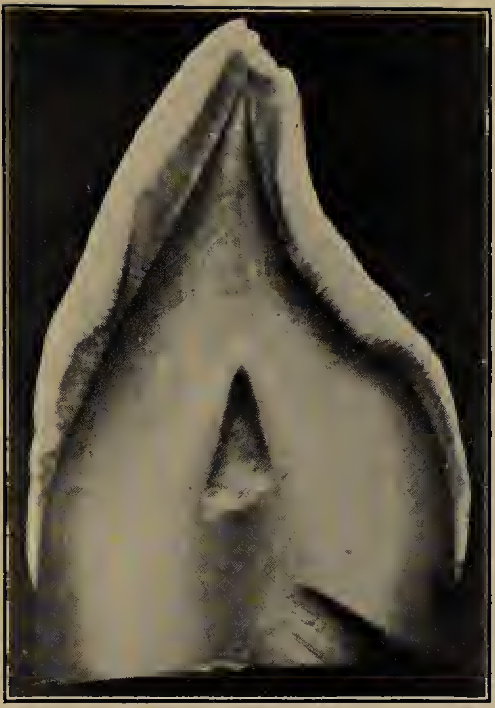

FIG. 52

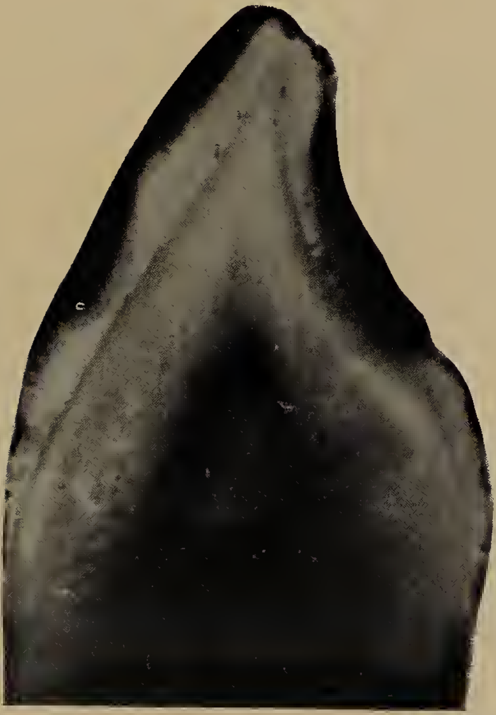

FIG. 53

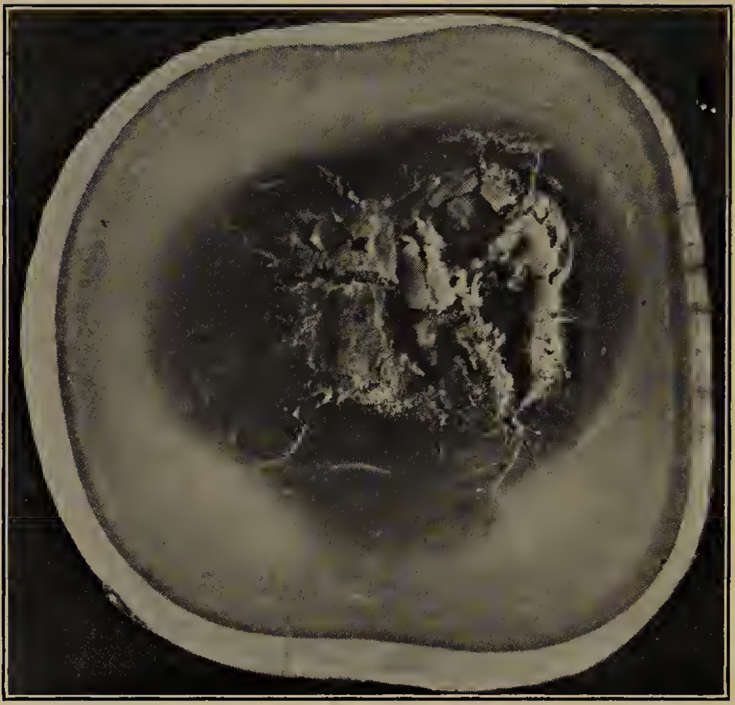

FIG. 54

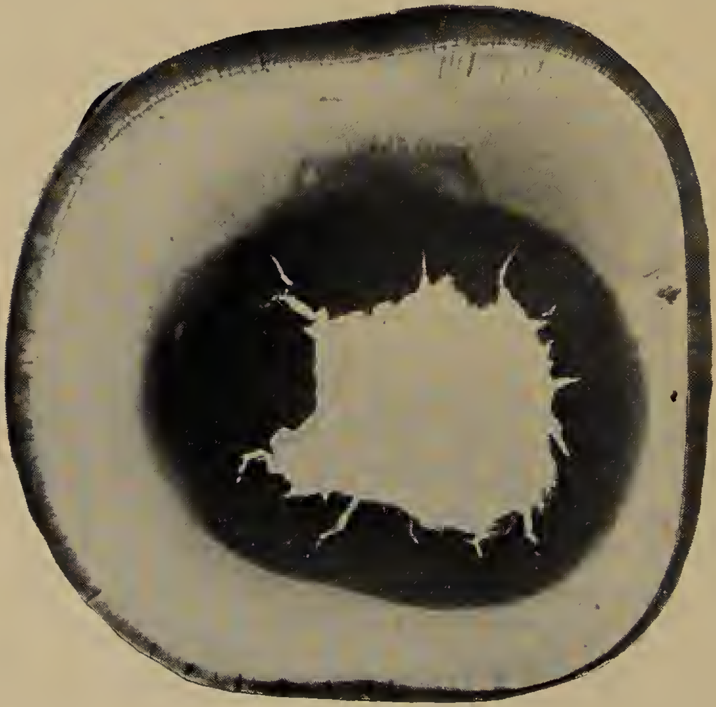

FIG. 55

In deciding to reinvestigate the structure of enamel I was influenced also by the work of Professor Gies, who succeeded in passing aqueous fluids through the enamel by way of the pulp chamber and the dentine, and also from the surface inward. This work, which has occupied a considerable part of my time during the past two years, not only has confirmed the findings of other investigators as to the permeability of enamel but has also demonstrated (what was not clearly known before) the nature of the channels through which the circulation or passage of fluids takes place.

"As I look back now upon my belief that enamel was an unstainable tissue, I am astonished and somewhat puzzled to know how I missed making the experiments which would have demonstrated my mistake. But my wounded vanity is somewhat soothed by the knowledge that in holding this belief I had the support of so acute and able an observer as my old friend, Dr. G. V. Black.

* * *

"Let me say, then, at the outset, that I have not found any human tooth which is not permeable to stain in some part of its enamel structure. My method has been to stain the tooth in bulk before sectioning. I would not regard the staining of sections of enamel as a satisfactory method, in itself, of demonstrating the real structure of this tissue, although important corroborative evidence might be obtained in this way. When a stain passes from the pulp chamber through the dentine and enters the enamel, or when it enters and penetrates the enamel from the unbroken surface of the tooth, there has been demonstrated at least the possibility that solutions which might form chemical combinations may pass into the tooth in a natural way during its life period. I say no more than that the *possibility* of such a phenomenon has been demonstrated; but that is a decided step in advance of what has heretofore been the view of the majority of our most eminent dental histologists.

"As the photomicrographs which I am to show you present a number of aspects that are new, and as these new views are due entirely to staining effects, I think it will be well to say a few words more on this subject of staining. Perhaps I can best bring before you the full significance of these views of stained enamel, as compared with unstained specimens, by asking how much we should know today of tissue and cell structure if staining methods had never been employed. What should we know of the wonderful processes of mitosis, of centrosomes, chromosomes, asters, spindles and polar bodies but for the staining agents which have been used in demonstrating these features of cell changes? So it is with enamel, although in a less degree. As we shall see, staining has thrown a flood of light on the structure and condition of forming enamel, completely formed normal enamel and pathological enamel.

"While a number of stains with which I have experimented enter enamel freely, notably eosine, indigo eosine, chloride of gold and nitrate of silver, I have found that a solution of silver nitrate (2% to 5%) greatly excels all others in its selective quality. Eosine and also gold chloride have the character of a diffused stain. The substance of the enamel rods appears to be stained about the same as the inter-rod substance. Not so with silver nitrate. This very markedly first stains the periphery, or a portion of the periphery, of the enamel rod. I shall speak of the significance of this later. In many instances the stain, if the action is continued long enough, will penetrate every part of the enamel. The nitrate of silver stain presents three distinct appearances. Occasionally, although not often, the stain will be, in some areas, pale violet. In nearly all specimens some areas will be clear orange and others quite black. Nitrate of silver marks every slightest trace of imperfection in the structure of enamel whether congenital or acquired. This agent reveals the fact that while there are great variations in the permeability of enamel there are but very few teeth that are even approximately perfect in the structure of this tissue, if by that word 'perfect' we mean 'impermeable to stain.'

* * *

"The investigations which I am about to describe embrace three distinct series of studies: mottled enamel; the enamel of fully formed but unerupted teeth; and the enamel of mature teeth in normal and pathological conditions. The striking and illuminating thing about these different studies is seen in the light that one throws on the others. . . .

"Mottled enamel is an endemic dystrophy of this tissue which seems to be confined largely to certain areas in the Rocky Mountain country, notably Colorado, although specimens are found in various parts of the world. The teeth are characterized by a dead white or milky white appearance, which is varied by brown and yellowish brown spots and bands. The condition of the enamel which produces this appearance varies from about one-fourth to the entire thickness of the tissue. In the majority of the specimens which I have examined the imperfectly formed tissue has been from one-third to one-half of the entire thickness of the enamel.

* * *

"I select for my first study an upper cuspid which seems to the unaided eye quite perfectly formed except that it is paper-white in appearance. Using a thin disk, I split this tooth longitudinally through the center of the crown. I polish the cut surface of one half and photograph it by *reflected* light under a power of about ten diameters. The appearance is as shown in Figure 52. A white band extends around the outer part of the cut surface, occupying one-half and in some places more than one-half of the thickness of the enamel. Inside this white band, extending to the dento-enamel border, there is normally formed tissue. After being photographed by reflected light, the specimen is placed in a 5% solution of silver nitrate for a few hours. The cut surface is ground away to remove any surface deposit and a section is made, mounted in balsam and photographed by *transmitted* light with the same lens that was used in the first specimen. (Figure 53.) Here we have all the conditions of light and shade reversed. The outer band, which was white by reflected light, is now, by transmitted light, quite black. The stain has rapidly penetrated the paper-white area of enamel, but has stopped at the beginning of the normally formed tissue.

"I now cut a lower molar transversely at about the middle of the crown and photograph the cut surface as before. In this specimen it is seen that the entire thickness of the enamel is paper-white. (Figure 54.) After being photographed by reflected light, the specimen is placed in an alcoholic solution of eosine. The stain penetrated the entire thickness of the enamel in ninety minutes. (Figure 55.)

"These specimens sufficiently familiarize us with the fact that stains will rapidly penetrate that defective condition of the tissue known as 'mottled enamel.' . . . Exactly what is the character of this defective enamel which permits stains to enter so rapidly? To determine this we must examine oblique and transverse as well as longitudinal sections of the enamel rods under high-power objectives, which, with an ocular magnifying ten diameters and various camera extensions, will give magnifications ranging from 600 to 3000 diameters. This reveals a whole new series of facts never before shown.

* * *

"I have found my most instructive studies at the inner border of the stained areas, that is to say, just where the defective enamel merges into the sound enamel. Figure 56, under a power of about 400 diameters, shows these areas finely. The enamel rods are cut exactly transversely, and we see at the first glance that the circumference of each enamel rod is outlined in black. In other words, the border of each enamel rod is the first part of the tissue to take the stain.

"Figure 57 is from a specimen cut somewhat obliquely to the course of the enamel rods. The place where the rods are seen to change direction represents the border line between the paper-white, defective enamel and the more perfectly calcified tissue. There is a small area of sound enamel shown on the left of the photograph. Immediately to the right and above this we enter an area in which the enamel is permeated with large canals, but we also everywhere catch glimpses of

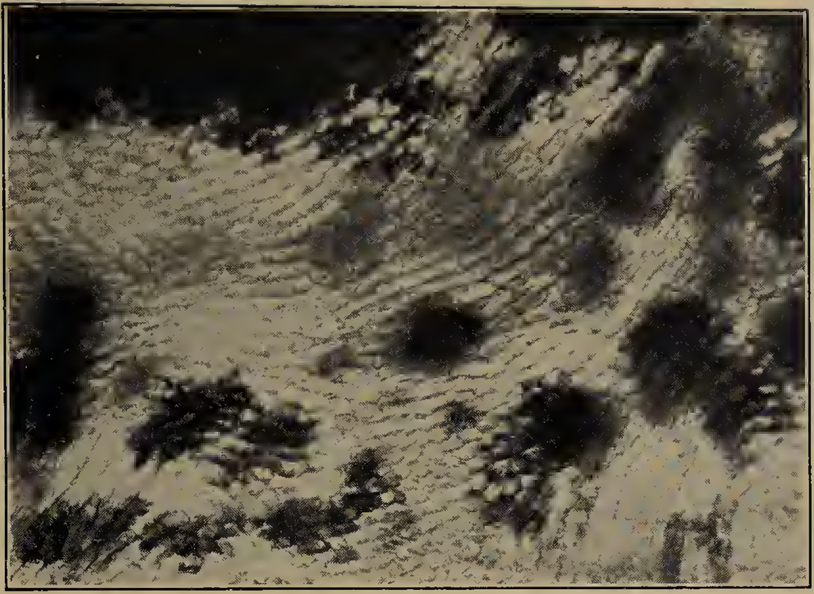

FIG. 56

Mottled enamel showing border line between normal and defective tissue.

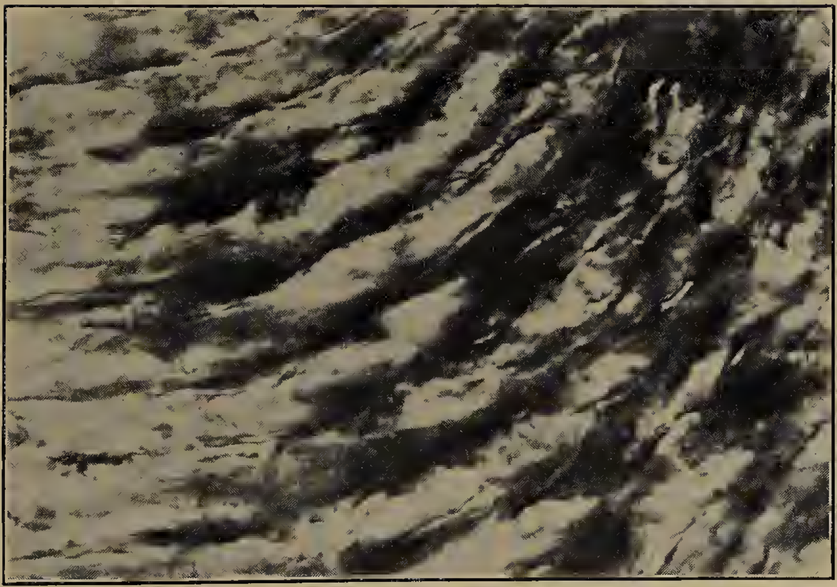

FIG. 57

Longitudinal section of molar showing mottled enamel under high power. At the left, normal enamel; at the right, very defective calcification of cement-substance and rods.

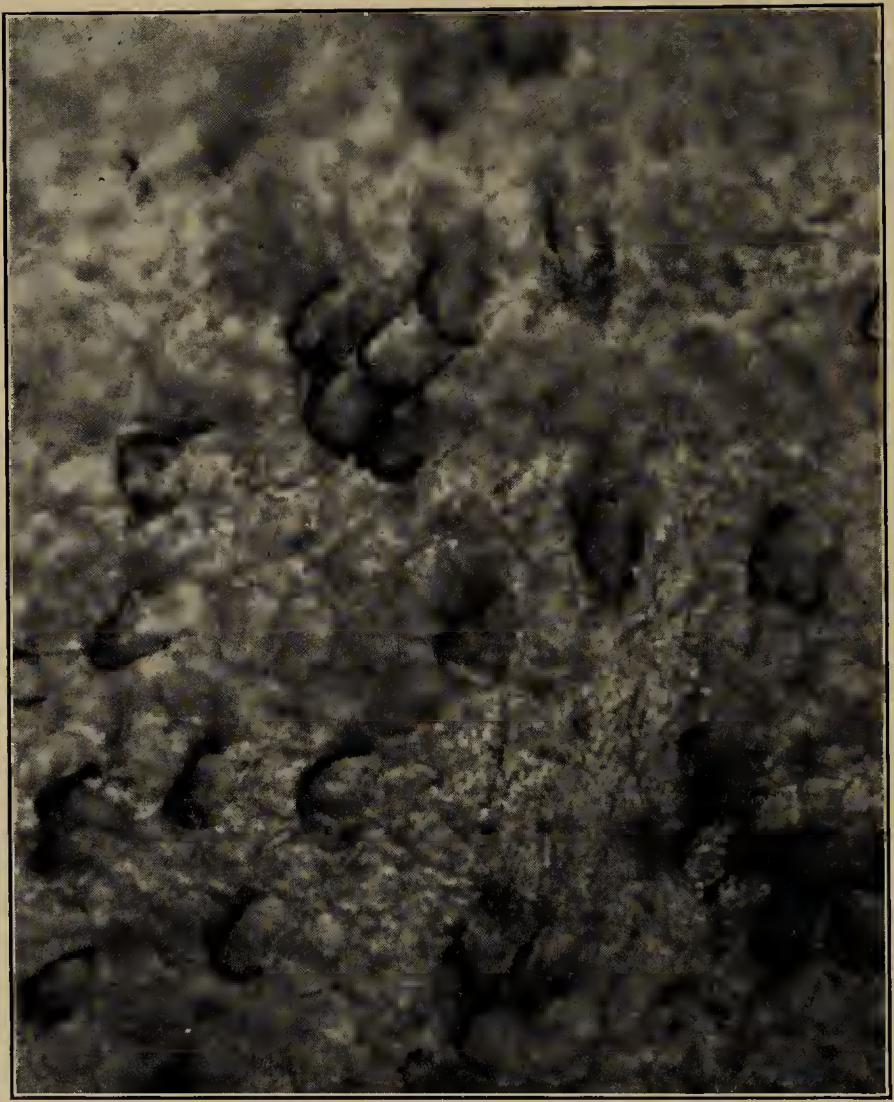

FIG. 58

Mottled enamel. Compare with Fig. 59 and also with Fig. 72, which shows earliest stages of caries of enamel.

that sharply defined black line defining the enamel rod. I wish to keep your minds fixed on the fact that this line is distinct from the large canals. . . .

"Figure 58, under a power of about 1000 diameters, gives a very striking picture of the condition of this defective enamel on the border line of the more perfectly calcified area. Please observe closely that not all of the substance between the enamel rods is stained. Each rod, as I have said, is very sharply outlined in black as if a pen-line had been drawn around it. Now, the space between enamel rods varies considerably in different specimens, but this sharply defined line is always the same in all specimens. As we shall see, it is quite distinct from the larger canals which we find, to a greater or less extent, in all enamel. As we approach the more defective tissue, these sharply defined lines often become confluent with the larger canals. This condition is shown in Figure 59 with all the distinctness of a pen and ink drawing. . . .

* * *

"It was Dr. Black's opinion that the defect in mottled enamel was largely or entirely confined to the substance between the rods. This opinion must have been based on an examination under low and medium powers of the microscope. With the high resolving power of the 2-mm. and 3-mm. apochromatic objectives we see that the enamel rods are very imperfectly calcified. From my own point of view of the method of enamel calcification this is just what we should expect. Anyway, it is the fact.

"Figure 60 shows an aspect of imperfect calcification of the enamel rods as seen in longitudinal section under high powers of the microscope. Imperfectly fused granules and small spherical bodies are everywhere in evidence in this specimen. Some of these larger globular masses appear to be identical with what have been hitherto described as 'calcospherites,' but the appearance in this specimen clearly indicates that the chemical changes in forming enamel and its molecular structure are more complex and intricate than the inferences we might draw from former descriptions of the formation of this tissue.

⁂

"As the condition of mottled enamel is due to imperfect calcification, it occurred to me that a microscopic examination of the nearly completed but unerupted crowns of teeth might throw some light on the main theme. I was fortunate in being able to secure the skull of a large monkey in which the first permanent molars were in place and the crowns of the upper centrals and some of the other teeth were nearly ready for eruption. Here we should expect to find the formation of enamel nearly finished but the processes of calcification or solidification not quite completed. Several of these teeth were removed from their crypts and treated with nitrate of silver solution for varying lengths of time precisely as were the specimens of mottled enamel. It was noticeable at once that these teeth, before being placed in the stain, had the paper-white appearance so characteristic of mottled enamel. And, as we shall see, the reason for this appearance is the same—the enamel was not completely calcified or solidified. . . .

"Figure 61 is from a longitudinal section of an upper central incisor. The formation of the crown of the tooth is nearly completed. The dentine and about half the thickness of the enamel were quickly stained with silver nitrate solution. On the buccal surface, inside the stained area, we have a fine view of the Schreger bands, which are due to the spiral arrangement of the enamel rods. . . .

"Figure 62 shows an aspect of stained enamel, from an unerupted tooth, in longitudinal section. The appearance so closely resembles mottled enamel that it would be quite impossible for me to distinguish between them. Here, as in the imperfectly calcified tissue of mottled enamel, it is the exterior portion of the enamel rod which first takes the stain. This is beautifully shown at the border line of the stain as seen under high powers. . . . Let us look at some portions of this area under greater magnification. (Figures 63, 64.)

"If I had not previously seen these views and some one were to ask me this question—'Is that a view of mottled enamel or incompletely calcified forming enamel or enamel in the early stages of decay?'—I have to confess that I should be unable to answer the query. The reason for this will, I hope, be made plain as we proceed. You will remember that I said, at the outset, that for me the chief interest of this investigation is found in the relationship shown between what would seem, on first thought, totally unrelated conditions, and also in the light which these facts throw on the method of enamel formation.

* * *

"The sharply defined line surrounding the enamel rod which the first effect of the stain shows is seen in Figure 64 and is the same as in mottled enamel. In some specimens, as in Figure 65, the rods are so closely packed together that only the black outline is seen, there being but little cement-substance required to unite the rods. But the proof that this line is not what has heretofore been called the 'interprismatic cement-substance' is found in the fact that in many of my specimens an unstained area is clearly seen between the rods *outside* this black line. This is finely shown in the longitudinal section of enamel under a power of about 2000 diameters, as seen in Figure 66. Here the border of each rod is shown sharply defined by a black line, but outside these black lines and between the rods there is an unstained area. This black line occupies the position of the limiting cell membrane of the ameloblast, but whatever interpretation is placed upon it, the fact must be recognized that it is a discrete substance. . . .

* * *

"There are many other aspects of this phase of my subject which I should like to dwell upon, but the limitations of time make it necessary to pass to the third and last section of my paper, which is devoted to the stained appearances of the early stages of caries in specimens of what would generally be regarded as normal human enamel. Let me emphasize the fact that nearly all of these specimens were selected from mouths showing exceptional freedom from decay, and in all instances, unless otherwise mentioned, the critical dentist would have passed these teeth as perfectly sound. That fact should be kept clearly in view in order to understand the full significance of what I shall show you.

"Let us pass rapidly in review a few specimens of incisors, bicuspids and molars which were first stained in bulk and then sectioned and prepared for the microscope. (Figures 67, 68, 69.) These photographs demonstrate two facts with striking clearness:

(1) Teeth specially selected for their apparent soundness and perfection are seen to have defective areas which the stain enters readily and rapidly.

(2) The stain enters also the most perfectly formed enamel, although more slowly.

* * *

"Let us now examine enamel in the early stages of caries. As I have previously pointed out, the necessary procedure in preparing balsam-mounted specimens for the microscope nearly always destroys or removes the bacterial plaque, but at the same time it reveals certain structural features of the enamel more clearly than can be seen in water- or glycerine-mounted specimens. Figure 70 shows a specimen in which the acid of decay has penetrated the entire thickness of the enamel. The stain has entered this area so completely that nearly all detail of structure is concealed. One of the most interesting phases of this early stage of caries is the reaction and change which we nearly always find in the dentinal tubuli *before there is any complete breaking-down of the enamel.* The nature of this change in the dentine and the reason for it are not well understood. . . .

"Figure 71 shows the border line between carious and sound enamel very beautifully. Here the appearance of the carious enamel is exactly the same as is produced by etching the surface of a section with lactic acid.

* * *

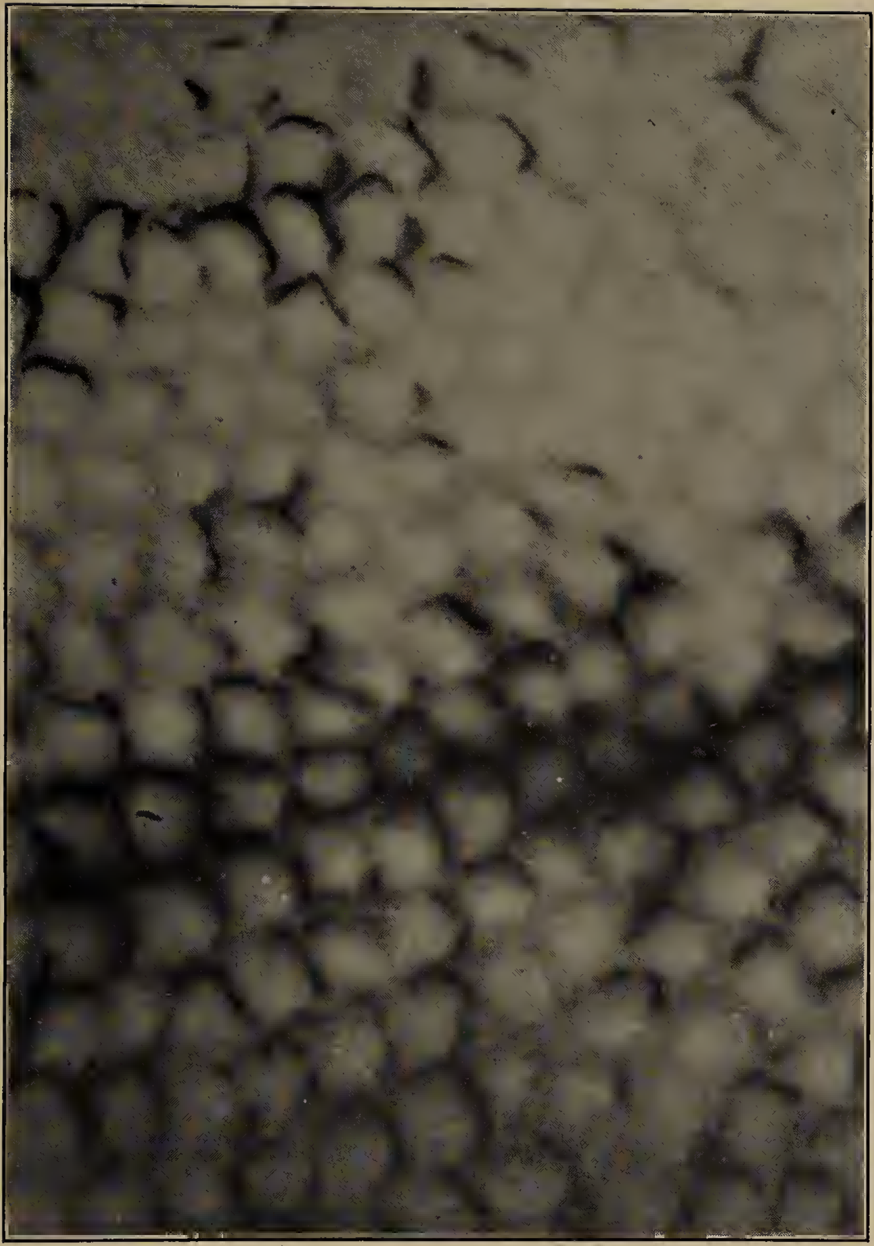

FIG. 59

Mottled enamel under power of about 1200 diameters. The defective tissue, as shown by the stain, is seen to appear always first in the sheath which surrounds the enamel rod. In the more defective tissue there is imperfect calcification of cement-substance and enamel rod.

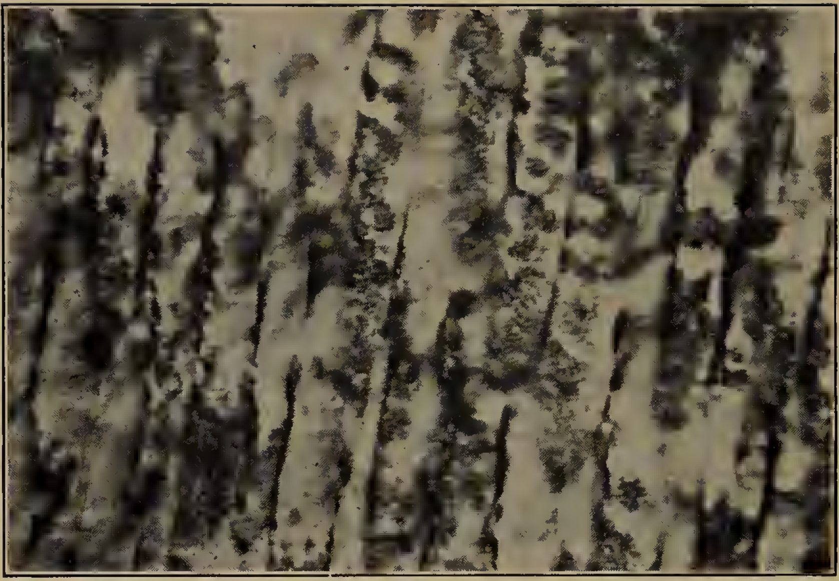

FIG. 60

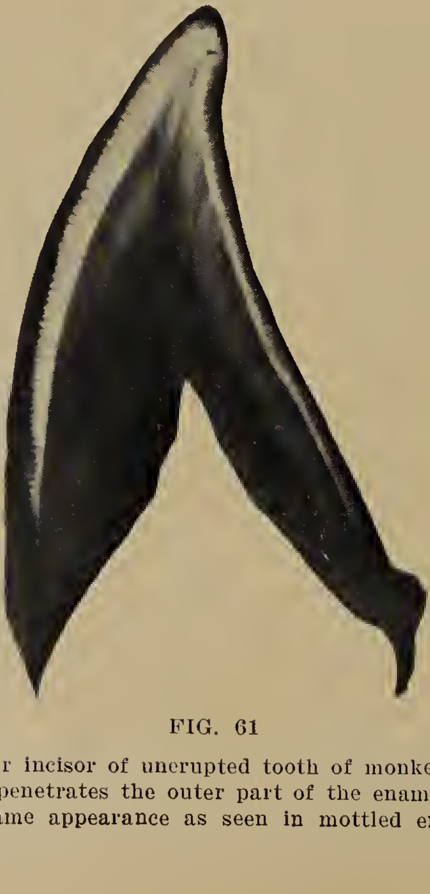

FIG. 61

Section of upper incisor of unerupted tooth of monkey. The nitrate of silver stain penetrates the outer part of the enamel, giving much the same appearance as seen in mottled enamel.

"We pass to an examination of a few transverse specimens of carious enamel under magnifying powers of from 600 to 2000 diameters. In these views the whole story of the carious process is told, as far as the mechanical aspects are concerned. In Figure 72 we begin, at the top, with the very commencement of the carious process. In most instances it is not a round or irregularly-shaped canal that we find as representing the initial action of decay, but the stained area is, as I have said, a sharply defined area corresponding with the circumference, or a part of the circumference, of the enamel rod. Except where the rods are packed very closely together, there is an unstained area between the rods outside this sharply defined line. This is a new fact in the histology of enamel and shows that the outside of the enamel rod is bounded by a discrete or differentiated substance. The formation of enamel is not quite the simple process that some dental histologists would have us believe. There is very much more to be learned about it. As we pass toward the lower part of the picture, we observe these black, crescent-shaped spots becoming larger and larger as the processes of decay melt down the walls of the channels, until, near the bottom of the view, the channels have nearly coalesced and the enamel is just on the point of breaking down into a cavity. . . .

* * *

"Figure 73 is from a tooth which I picked up in the catacombs of a very ancient monastery at Syracuse, Sicily. This tooth had probably lain there for fifteen centuries or more. The stained, black outline of the enamel rods is clearly shown and outside this black line may be seen, in several places, a distinct unstained area which is the true cement-substance. In all of these specimens this stained area, which surrounds the enamel rod like a sheath and occupies a position corresponding to that of the cell wall in the ameloblast, seems identical with the stained area shown in the specimens with which Dr. Bodecker illustrated the paper which he read before the National Association two years ago and which he believed represented organic matter. If this opinion is correct, then we have to recognize a form of organic matter which may lie unimpaired in the ground for an indefinite time.[1]

"What is the nature of the space on the circumference of the enamel rod which is represented by this black line? . . . I think that we may assume that this line represents a distinct discrete substance different from the enamel rod or the cement-substance which lies outside this line. It is much more selective to stain than the other parts of the enamel. In mottled enamel this outer part of the enamel rod is imperfectly formed. It is evidently in a soft or cartilaginous condition, and in dried specimens is largely a space filled with air. . . .

* * *

"Figure 74 is an exceedingly interesting specimen. It represents a section of mottled enamel from a tooth lightly stained in bulk with nitrate of silver which was first ground to a thickness of about 1 mm., polished on one side and cemented to a glass slide with Canada balsam. After this had hardened, the section was ground to a thinness of about five microns and treated with a 3% solution of lactic acid until the enamel was nearly decalcified. Something very important is revealed at *a,* which represents the surface of the enamel. A very distinct line is seen here which occupies the position of Nasmyth's membrane. In mounting, pressure on the cover glass has forced the membrane away from the surface of the enamel. But the arresting thing to which I especially call your attention is those lines which pass from the membrane to which they are attached down *between* the enamel rods. These lines undoubtedly represent a cross section of the sheaths of the enamel rods to which I have already called your attention. Some of these lines have been destroyed in the process of grinding, but all of those that remain can, in the original photograph, be clearly traced as passing between the rods.[1]

"We have here evidence that seems to me very nearly conclusive that the periphery of the rod is the last part to be calcified. The appearance is as if the energies governing calcification became somewhat exhausted toward the finish of this process and were not quite able to supply sufficient calcific material for filling in the inter-rod spaces. This view finds confirmation in the fact that the outer portion of the enamel is nearly always the most defective in this respect.

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[1] See Addendum to this paper.

"In nearly all cases of mottled enamel it appears that something happened quite suddenly, when the process of calcification was partly completed, which prevented the normal physiological processes concerned with calcification from functioning properly. To find out just what happens at this stage will, I fear, prove a somewhat baffling problem.

"In caries of enamel the tearing-down process is the reverse of the building-up process. In enamel formation calcification ends with the completion of the inter-rod substance. The beginning of the carious process is in the dissolution of this inter-rod substance. This last-formed material is less resistant to the acid of decay than the substance of the enamel rods. If, as I contend, the enamel rod represents the calcified cytoplasm of the ameloblast, this is exactly what we should expect, but it is to be clearly understood that this want of resistance does not apply to the sheath of the enamel rod. That is more resistant to acid than any part of the enamel except Nasmyth's membrane.

* * *

"There is one very important phase of this subject to which I wish especially to direct your attention. When examining the unerupted teeth of the monkey, I called your notice to the so-called enamel 'whorls.' These whorls have been looked upon as imperfections in enamel formation. I regard this as one of the most serious mistakes that have been made in the histology of enamel. These enamel whorls represent the spiral formation which is fundamental to all the best types of enamel. These spiral arrangements of the enamel rods are found in greatest abundance in teeth which have to bear the greatest stress, as in the molars and bicuspids. They are also more abundant on the lingual surfaces of the upper incisors than on their labial surfaces. I have made a rough calculation, based upon counting the numbers in transverse and longitudinal sections, and I conclude that there are from 8,000 to 10,000 of these spirals in a molar tooth. . . .

"Now, the center of these spirals is tubular. When staining fluids enter the enamel by way of the dentine, the stain always enters first the center of each spiral. . . . When the stain enters from the surface of the enamel, it passes through the thickness of this tissue and enters the dentine by way of the tubes in the center of the enamel spirals. . . . In transverse sections of the spirals these tubes or canals are very clearly shown. (Figure 75.) . . .

* * *

"We have now demonstrated that fluids may enter the enamel by way of the tooth pulp and the dentine, and also from the surface. The way is open for calcific material to enter the enamel by way of the dentine and to be deposited there, thus increasing the solidity of the enamel, if such process is possible under the conditions governing constructive metabolism in the human body. Have we any evidence that such metabolism occurs? None whatever, as far as I can see at present.

"Just consider for a moment the condition we have in mottled enamel—an open, loosely constructed condition of this tissue. If a building-up and consolidation of enamel could take place by means of calcific material brought into it by way of the dentine, here is the most striking condition in which such phenomena might be exhibited. We might say that here nature has a great opportunity for showing what she can do in the way of repairing defective structure. But when mottled enamel from the mouths of people fifty or sixty years of age is examined, do we find any evidence that forty years' functioning of the dental pulp has improved the structure of the enamel? Not the least, as far as I know. The teeth present the same opaque white ap-

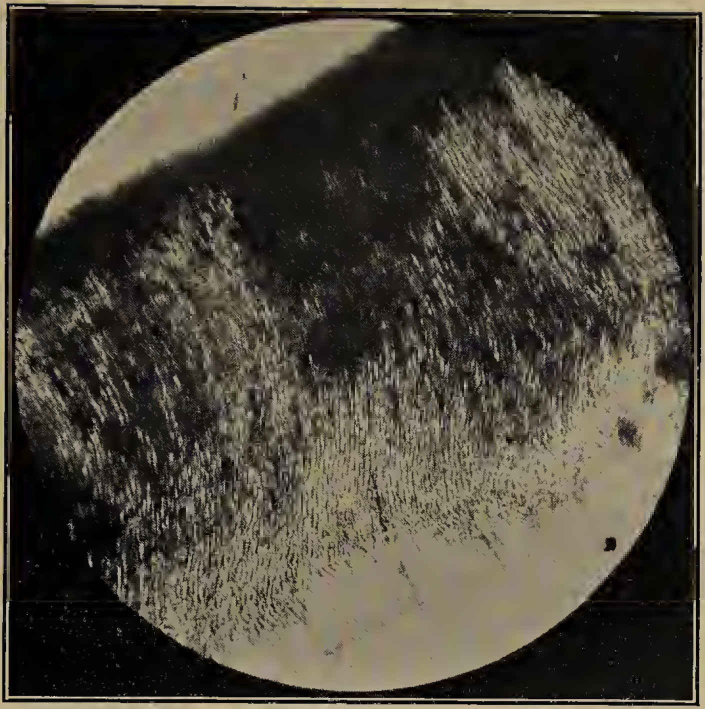

FIG. 62

Incomplete calcification in unerupted tooth of monkey.

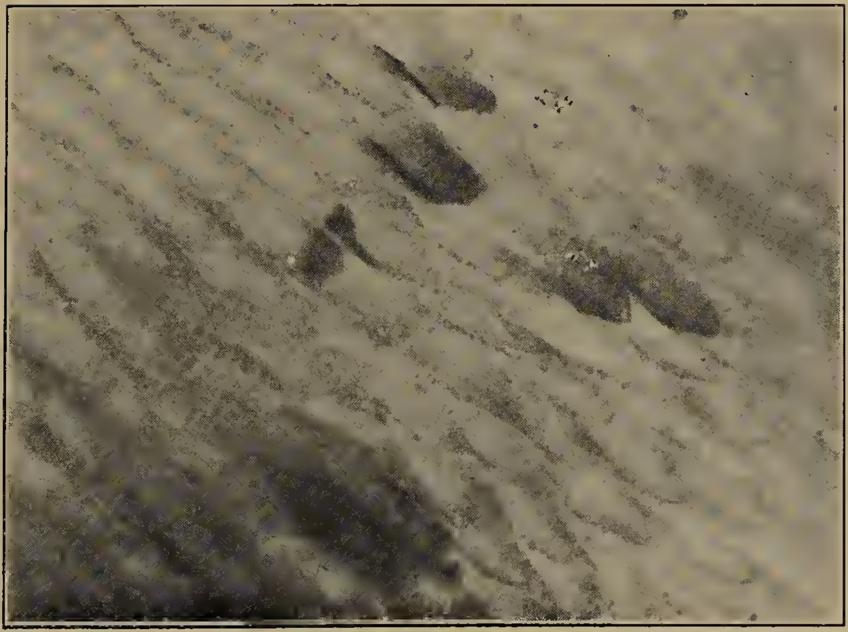

FIG. 63

Incomplete calcification in unerupted tooth of monkey.

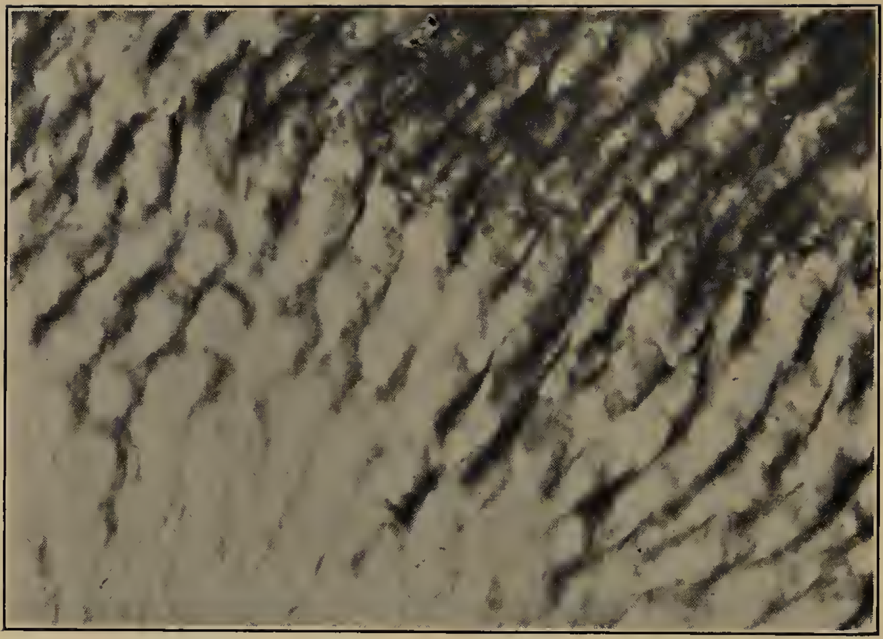

FIG. 64

Oblique section through enamel of incisor of monkey, magnified about 1200 diameters. Tooth fully formed but unerupted. The rod-sheaths are shown stained black and the general appearance closely resembles mottled enamel.

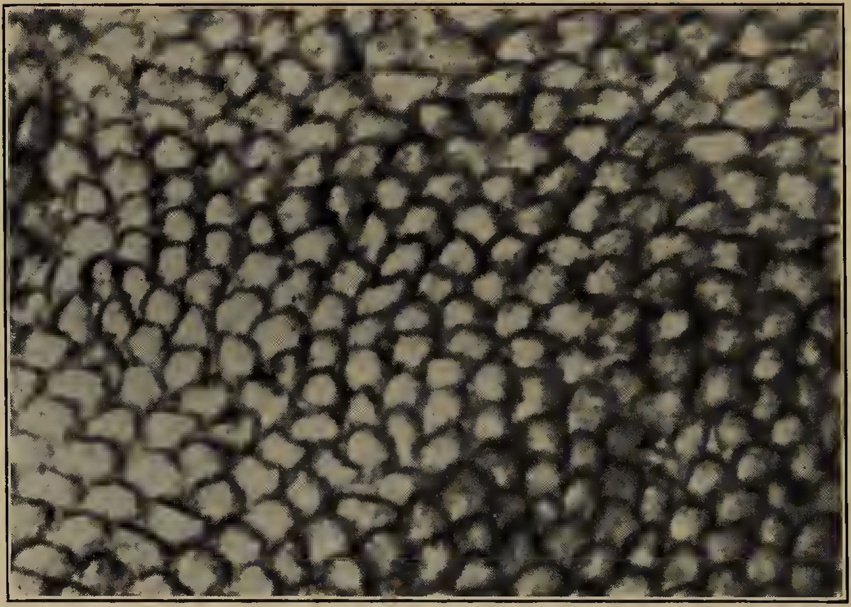

FIG. 65

From another specimen similar to Fig. 64. The surface of the three foregoing specimens was slightly etched with a weak solution of lactic acid to bring out more clearly certain structural features of the enamel rods and their relations.

pearance at sixty as they do at sixteen. Stain enters the enamel freely and rapidly in the older teeth as in the younger. But we saw that in unerupted teeth—and the same thing is true of recently erupted teeth—stain enters the enamel much more rapidly than in older teeth. What is the explanation of this?

"My present view is that hardening processes may go on in enamel for a long time, perhaps for many years, *without the addition of any new material.* There is nothing surprising in this. Is it not exactly what occurs in all mineral cements? I think of the process as a *tightening of molecular grip.* Perhaps there is a slowing-down of the rate of molecular or atomic vibration. I greatly doubt if there can be any metabolic or physiological action, any true nutrition, in any tissue in the absence of the cells which we believe govern or control all of these activities.[1]

* * *

"My view of the method of enamel formation, a method which I think explains some of the new views of enamel structure which we have been examining, is that the enamel organ has two distinct functions. The function of the ameloblasts is to give form and character to the enamel rods. The enamel rods are the calcified ameloblasts.

"The stratum intermedium is the secreting part of the organ. In the rodents, the fishes, and to a less degree in many other animals, the stratum intermedium shows all the characteristics of typical secreting structures. This part of the enamel organ selects the calcific material from the blood. This albuminlike material has been called 'calcoglobulin.' Calcification begins in small spherical masses which are called 'calcospherites.' They first appear near the lower end of the ameloblasts. The *calcific* material of the enamel rod and the inter-rod substance is identical. The difference in appearance of ground sections in enamel rod and inter-rod substance is due to the cytoplasmic structure of the ameloblast. This calcified, cytoplasmic substance of the enamel rod naturally offers more resistance to the process of decay than calcific material alone. Imperfect calcification is probably due to imperfect functioning of the secreting part of the enamel organ. We are just beginning to learn something of the intimate relations of the secreting organs of the body, and it is highly probable that we shall sooner or later discover that mottled enamel and other similar conditions of this tissue are due to a disturbance of balance in the functioning of the endocrine glands.

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[1] See Addendum to this paper.

* * *

"We are always primarily concerned with facts—they must have first consideration. And here are some of the important facts which we have to face and explain in our efforts to solve the problem of dental caries. While we find a considerable variation in the permeability of the enamel of different teeth, we find that the enamel of all teeth is permeable to some extent. All enamel is most permeable on its surface. Where a stain can enter the enamel we have no reason to suppose the acid of decay may not enter. We have shown in this paper how the acid of decay begins its work in caries of enamel by the enlargement of those natural canals which are found in the outer layers of all enamel. This process begins beneath bacterial plaques which contain microorganisms capable of converting starch and sugar into lactic acid. As long as these microorganisms remain active as acid-producers, fastened to the surface of the enamel, this process of the dissolution of the enamel is bound to go on. But this process of enamel caries is sometimes arrested. Is that arrest due to some change in the chemical contents of the saliva which inhibits the action of the bacteria or to some buffer condition set up in the substance of the enamel, due to the circulation of a fluid in this tissue? These are questions which have not yet been answered.

* * *

"Another question which the facts force upon us is this: to what extent is faulty structure a predisposing cause of decay? I should say, 'Not in the least, unless the acid of decay is present.' It is a mistake, as I long ago pointed out, to assume that the absence of caries in the teeth of wild animals is due entirely or chiefly to more perfectly formed enamel than we find in the average human tooth. . . .

"When we come to examine sections of these teeth under the microscope, we frequently find evidence of imperfect calcification. . . . Faulty enamel does not necessarily mean decay, and the logical correlative of this statement is that the finest enamel that was ever formed will not resist the action of lactic acid as produced beneath bacterial plaques. There is nothing in this view which tends to minimize the great importance of the most perfect structure in enamel that can be produced, because the more imperfect the structure the more rapid will be the process of decay when the active or exciting cause is present.

* * *

"With reference to the part which food habits and nutrition play in dental caries my view is this: the proper balance and optimum quantity of all the essential elements are most important for the preservation of the teeth. The greatest importance of this condition is during the period of gestation and the first seven years of life. This period determines the quality of the structure of enamel. But, as we have seen, that is not all that is required to maintain the integrity of the enamel throughout life. A well-balanced diet throughout life is probably necessary to the maintenance of that buffer condition, whatever that condition may be, which inhibits the action of the acid-producing bacteria which are the active cause of decay. But even when all these food conditions are perfectly fulfilled, there will still be a wide variation in the liability of the teeth of different individuals to decay. There are other important conditions besides food elements which exert a powerful influence on nutrition. An examination of these conditions is outside the province of this paper, but it will not be out of place to call attention to the fact, most noticeable and significant in remote country districts, that in large families which have been brought up on the same diet there is great variation in the liability of the teeth of the children to decay. And, as I have long noticed, the same thing is true of different families living in country districts where the food habits are practically identical. There are doubtless some very subtle influences at work, perhaps chiefly conditions of heredity and endocrine balance, which determine this question of immunity or non-immunity to dental caries.

* * *

"There is just one more important phase of this problem to which I wish to call your attention. The work of Professor McCollum and others has shown that defective bones and teeth may be the result of an unbalanced diet. That, of course, means defective organization of the whole body. But evidently every other tissue in the body except the enamel of the teeth may be restored to a normal condition. Every community in this country could probably produce instances of people who, having lost their teeth early in life, yet continued to live in health and vigor until a ripe old age was reached. Is not this another proof that all recuperative power lies in cell activity? From this point of view it would seem that the enamel has no recuperative power because its formative cells are completely lost with the eruption of the teeth.

* * *

"We see, then, when our subject is viewed from all possible angles, that the outstanding fact seems to be that acid-forming bacteria are the active cause of caries of enamel. How to produce a permanent buffer condition in enamel, if such a thing be possible, is, therefore, our next great problem."

SUMMARY

"The special new features in the normal and pathological histology of enamel brought out in this paper may be summarized as follows:

(1) A sheath surrounding the enamel rod has been demonstrated *without decalcification.*

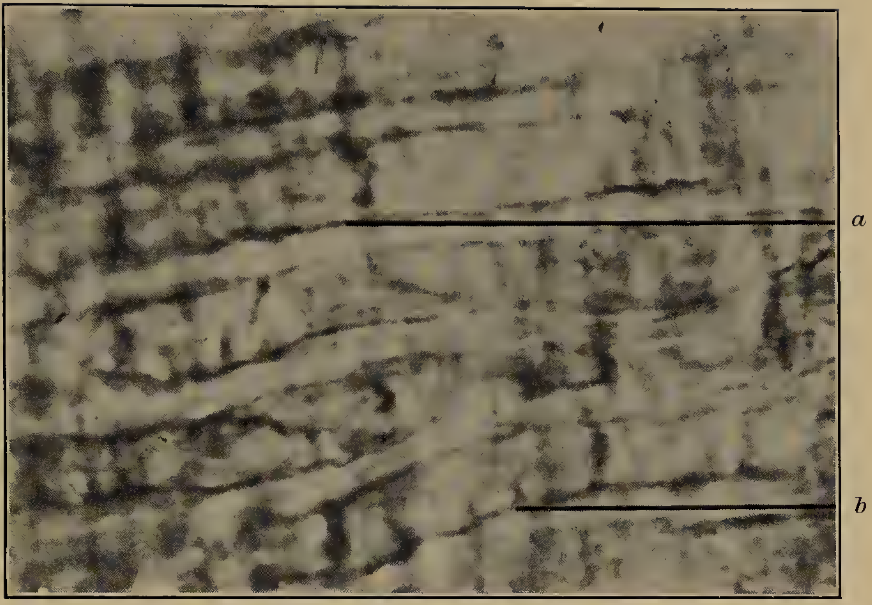

FIG. 66

Enamel rods from molar of monkey, magnified about 2000 diameters. Here the sheaths of the enamel rods in longitudinal section are finely shown deeply stained. Between the rods, *outside the sheaths,* considerable cement-substance is seen, as at *a* and *b*.

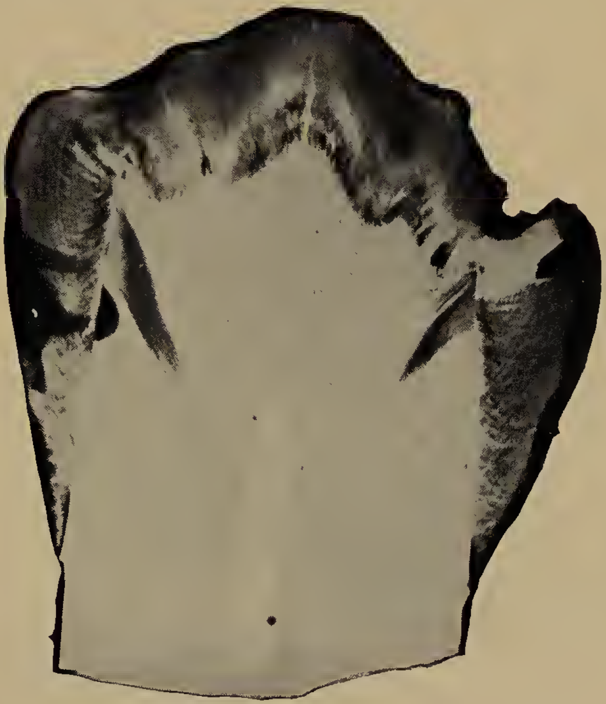

FIG. 67

An apparently sound bicuspid stained in bulk and sectioned. The staining shows many defective areas.

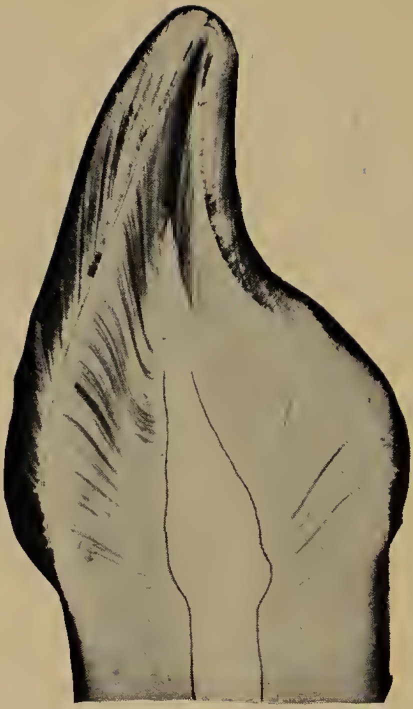

FIG. 68

Selected as a perfect tooth. The nitrate of silver stain penetrated the enamel everywhere.

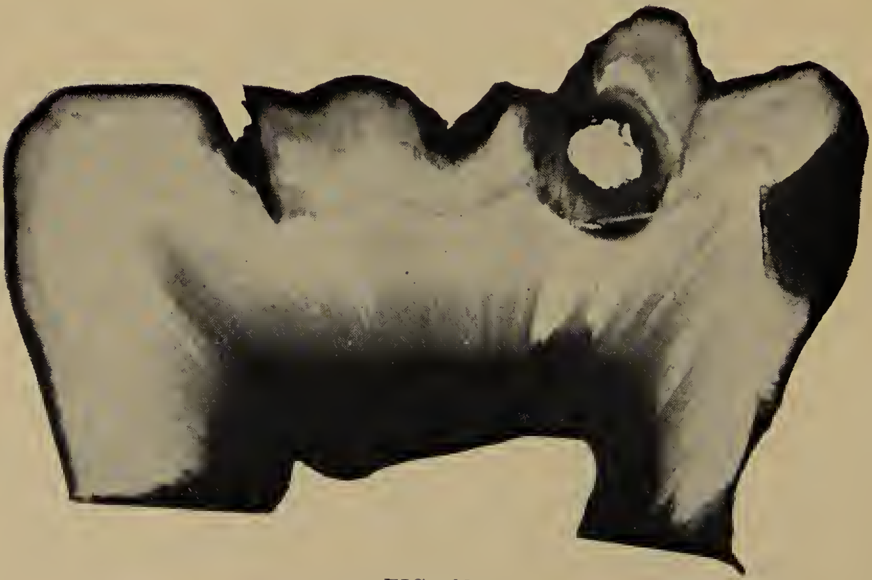

FIG. 69

Section of upper molar. Although it appeared to be a perfectly sound tooth, the stain shows many defects.

(2) This sheath is the first portion of the enamel to react to stains.

(3) This sheath appears to be in intimate relation with Nasmyth's membrane; in fact, firmly attached to and continuous with it.

(4) In normal, completely formed enamel this sheath stains evenly all around the rod.

(5) In mottled enamel and in the early stages of decay and, to some extent, in fully formed but unerupted teeth *a portion only* of the sheath stains sharply and rapidly, the stained portion extending half or two-thirds around the rod, thus showing in transverse sections a crescent or horseshoe form. This is an outstanding fact in the pathology of enamel and one for which I have no explanation to offer at present.

* * *

"The appearances of imperfect calcification in mottled enamel are of a very specific character. Three phases are clear in the illustrations which accompany this paper: (1) an abnormal condition of the sheaths of the enamel rods which causes them to react to stains much more quickly than in normal enamel; (2) the presence in the cement-substance, and contiguous to and apparently involving the rod-sheath, of numerous canals through which stains flow freely and quickly; (3) the presence of numerous granules and spherical bodies in the substance of the enamel rod which may indicate either abnormal chemical reactions or the arrest of those normal chemical processes which result in that complete fusion of substance and the resulting vitrified appearance which we see in perfectly formed enamel.

"That the condition of mottled enamel is due to imperfectly calcified material is demonstrated to a considerable extent by the very similar appearances shown in fully formed but unerupted teeth, in which the processes of calcification are not completed.

"All stains which penetrate the enamel through the pulp chamber and the dentine enter by way of canals which, in human enamel at least, are always to be found in the center of the enamel whorls or spirals which constitute the characteristic arrangement of the enamel rods.

* * *

"Caries of enamel is seen to begin with a change in the rod-sheath, which renders it more sensitive to stain; the enlargement of canals, which apparently exist in the most perfectly formed human enamel; and the formation and enlargement of new canals either in the substance of, or contiguous to, the rod-sheath. The only rational explanation of these appearances that has yet been offered is that they are due to the action of bacterial products formed beneath bacterial plaques, which products are known to possess the chemical power of dissolving enamel.

"Certain premises have been inferred or assumed, and from these premises by processes of deductive reasoning a conclusion reached that nutritive metabolic changes occur in enamel after eruption of the teeth. No microscopic evidence is available in confirmation of this opinion. All the facts in our possession point to the formative period of enamel as the time when the quality of enamel is determined for life.

"It is certain that all of the important facts concerning the effects of diet on enamel formation which recent experimental research has brought to light are mainly significant with reference to the period previous to the eruption of the teeth when the enamel is being formed.

"Our present information concerning the structure of enamel and the processes of decay of this tissue would indicate the possibility of producing a buffer condition against the action of those bacterial products which are the active causes of caries by the external use on the enamel of some chemical substance which might enter and permanently remain in the canals and spaces which are found in all human enamel."

ADDENDUM

The foregoing paper was read at Cincinnati, Ohio, on December 5, 1922. The temporary suspension of *The Journal of Dental Research,* in which this paper is to appear, has caused a somewhat lengthy delay in its publication. Quite recently—on January 2, 1925, to be exact—Dr. Williams's attention was called to an item in the London *Lancet* which referred to a paper in the *British Dental Journal* by Mr. H. C. Malleson, M.R.C.S., L.R.C.P., on *The Structure of Human Enamel as Revealed in Decalcified Sections.* This paper was read on April 9, 1924, before the London Metropolitan Branch of the British Dental Association. In this connection Dr. Williams writes:

"I looked up the issue of the *British Dental Journal* containing Mr. Malleson's paper and was delighted to find it a notable piece of work. . . . As Mr. Mummery very truly observed in his discussion of the paper, it opens up an entirely new conception of enamel structure.

"It is interesting to note in this connection that Dr. Charles F. W. Bodecker, formerly of Berlin but now Professor of Histology in the Dental Department of Columbia University, succeeded, several years ago, in demonstrating an organic matrix in decalcified enamel by methods very similar to those described by Mr. Malleson. Working in my laboratory during the summer of 1923, Dr. Bodecker repeated his experiments and subsequently presented the results of this work before the International Association for Dental Research in New York.

* * *

"I have decided to publish my own paper substantially as it was originally written and read and to add a few brief comments on the more recent work of Mr. Malleson, Dr. Bodecker and others as an addendum. The first thing to be said is that there is no doubt whatever about the organic nature of this sheath which surrounds the enamel rods. Professor William J. Gies, head of the Biochemical Department of Columbia University, has made a thorough test of the undissolved matrix of some of Dr. Bodecker's specimens and pronounced it organic matter. The first question that naturally arises, then, is this: what sort of organic matter is this and have we any evidence as to its function in enamel? In this connection Mr. Malleson makes a very pertinent and significant suggestion. He says: 'It may be asked: what is the nature of this cuticle? Is its structure the same as the translucent layer of Nasmyth's membrane and may not Von Ebner's statement that it is traceable into continuity with that membrane be correct?' I was not aware that Von Ebner had made this observation, but I believe that the illustration which I show as Figure 74 amply confirms this view. It is, I think, generally believed that Nasmyth's membrane belongs in the keratin group of substances, in which horn, hair, hoof, claws and nails are found. Professor Gies has called my attention to the fact that some of these substances, the material of hoofs, for example, possess considerable elasticity.

"My suggestion is that the sheaths of the enamel rods and Nasmyth's membrane are similar in physical character and chemical composition and that it is the elastic property of these sheaths which preserves the very brittle enamel from destruction during the stress of the mastication of hard substances. If the enamel throughout were equally hard and brittle we may reasonably conclude that, especially with the rodents and carnivorous animals, it would simply crack and go to pieces with such usage as these teeth get. This view makes the sheath of the enamel rod one of the most important features in this tissue.

* * *

"But there is at present a growing belief with some that nutritional changes, true metabolic activity, take place in enamel through the medium of this organic matter. If we wish to apply the term 'metabolism' to inorganic, chemical changes, then we may say that theoretically this is possible. Some are doing this. Dr. Percy Howe, for example, speaks in a recently published paper, of 'inorganic metabolism.' But we must not forget the saying of one of the great master minds that the first essential of sound thinking is a clear perception of distinctions and differences. Many chemical actions and reactions are included in cell metabolism, but

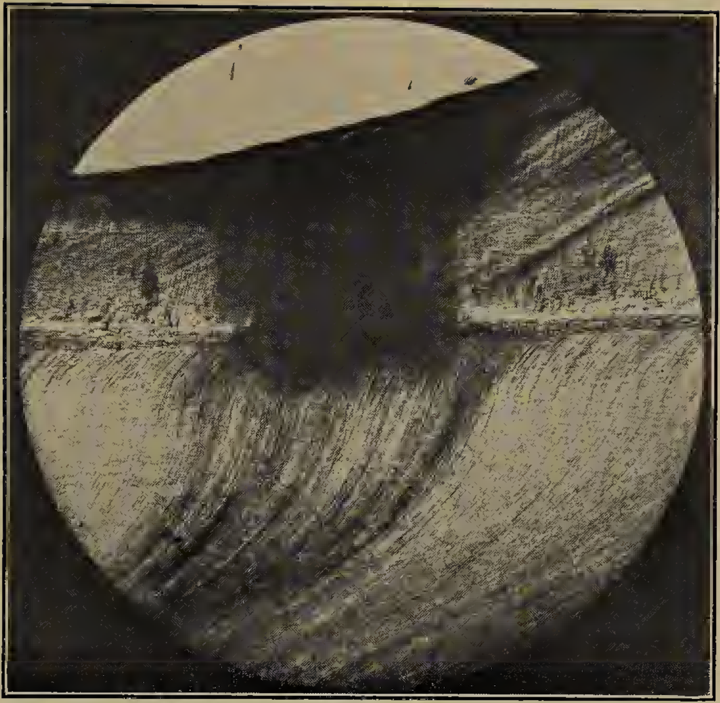

FIG. 70

This new series, showing early stages of caries of enamel, is introduced here for reasons given in the text. Fig. 70 shows that the process of decay completely penetrated the enamel and produced a marked reaction in the dentine before there was any appearance of an external cavity. The stain has completely obliterated all detail in the enamel. To show this detail one must stain more lightly, as shown in some of the following illustrations.

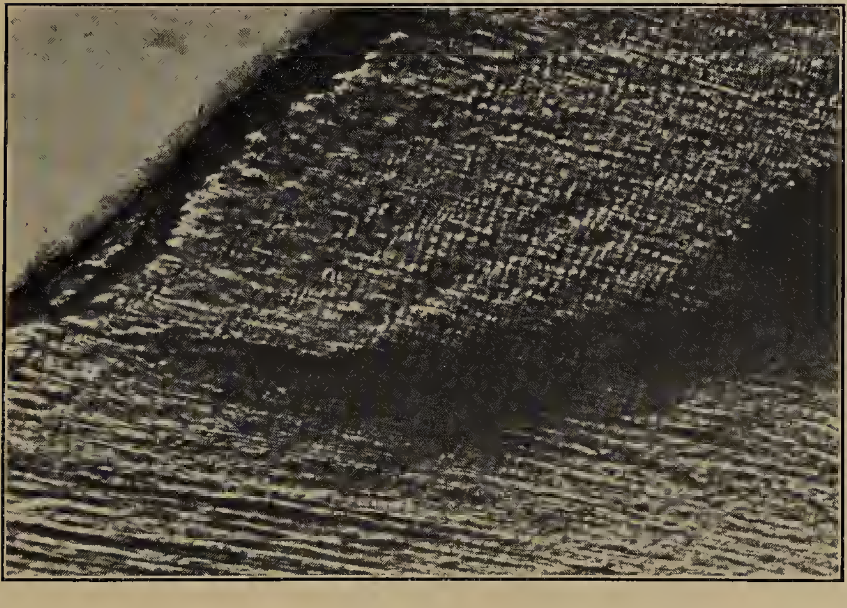

FIG. 71

Early stage of caries of enamel. The appearance of the enamel in the upper part of the view, where the acids of decay have penetrated, is identical with the appearance of enamel treated artificially with lactic acid.

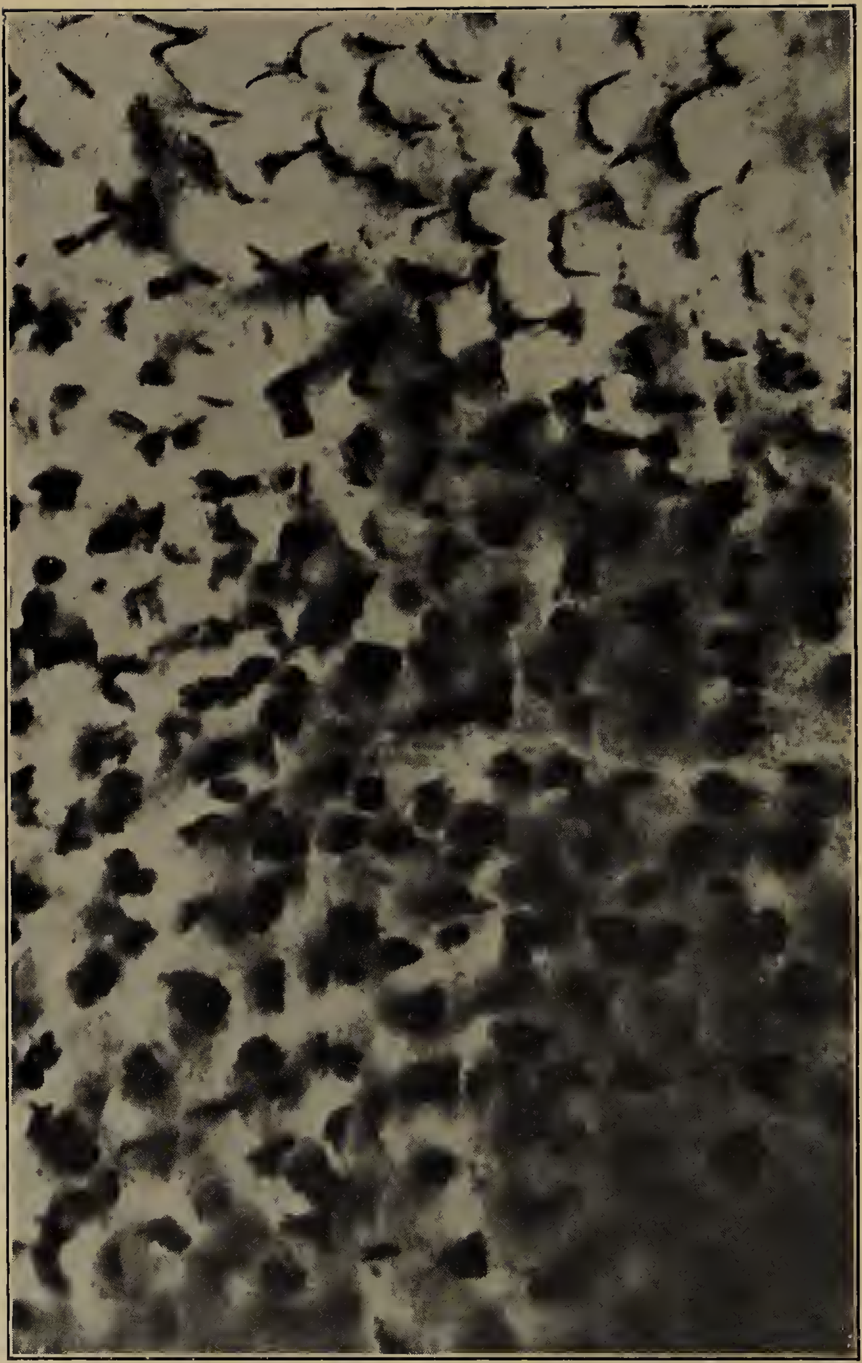

FIG. 72

Transverse section of enamel showing the progress of caries from the earliest stages, as seen in upper part of the view, to the point where the enamel is nearly on the point of breaking down into a cavity, as seen in lower part. Obj. 3, proj. oc. 6.

this great distinction and difference between inorganic chemical action and cell metabolism remains—one is the characteristic of dead things and the other of living things. Enamel is a product of cell metabolism, but when its production is completed the cells which produced it disappear. That is not true of any other animal tissue. With all other organs and tissues the formative cells remain, hence the possibility of repair and regeneration. Any material for the repair or regeneration of enamel from an internal source must come through the dentine-forming cells. But dentine-forming cells produce dentine, not enamel. Have we any evidence that there is ever a deposit of dentine in enamel? Have we any evidence that there is any sort of an amorphous deposit from the dental pulp of lime salts in enamel after the formation of enamel is completed? None whatever, as far as I know.

* * *

"Let us keep our feet on the solid ground of facts. Even the most insecure of hypotheses must lay claim to some facts to justify its existence, and I repeat that I know of no fact which warrants the claim that anything in the nature of true regenerative change takes place in enamel after the disappearance of the ameloblasts. I should be greatly delighted to hear that such a fact had been discovered. The day on which such a discovery may be made will indeed be a momentous one for humanity. But for the present I think the dental profession need have no fear that Othello's occupation will be gone on the assumption that nature has discovered a way to anticipate the results of her labors. And so I do not look upon this discovery of organic matter in enamel as giving the slightest warrant for the opinion that real, nutritional, metabolic changes are taking place in enamel.

"This conclusion is not in accordance with the hopes which I expressed in the opening of the paper on *Unsolved Problems in Dental Histology* which I read in 1921 before the International Association for Dental Research. I had hoped to find some evidence of reconsolidation of enamel after eruption of the teeth. After four years of the most painstaking search, during which more than one thousand photographs similar to those illustrating this paper have been made, no such evidence has been discovered. It seemed to me, when I found the readiness with which enamel could be stained, that the way was open for the deposit of calcific material in defective, porous enamel, not as true enamel but in a form which would increase its power of resistance. But I find that teeth in the mouths of elderly people, teeth which have resisted the powers of decay for a lifetime, often have an open, porous structure of enamel which stains quickly penetrate. I find the same condition in the teeth of animals, where caries is never found, but nowhere can I find any evidence that these canals, which greatly favor rapidity in the progress of caries *when the exciting causes of decay are present,* are ever consolidated or filled up.

* * *

"And there is another line of evidence that is almost conclusive that there is no improvement in the quality of enamel in erupted teeth even by 'inorganic metabolism.' Some six years ago Professor Gies injected Trypan blue into the abdominal cavity of a young dog whose teeth were in process of formation. All the tissues of the body were deeply stained. As the teeth erupted it was seen that the enamel which was in process of formation at the time the injection was made was deeply stained, but the enamel which was completed at this time was unstained. The stain rapidly disappeared from all the tissues *except the enamel of the teeth,* and now, after six years, that stain remains in the enamel without change. I have repeated this experiment with quite a number of animals, and always with the same results. Do these experiments not force the conclusion upon us that there is no vital circulation in enamel? . . .

"Circulation of fluid and organic matter of a sort there undoubtedly is in enamel. This fact is probably true of all teeth, but if the presence of this fluid and organic matter contributes anything to improvement of the quality of enamel, then why does not the quality of all enamel in all teeth gradually improve with age? If in reply the conjecture is put forward that the unknown conditions may not always be favorable, then I have to say in rejoinder that we can see and study, in all the different phases which are presented, the degenerative changes which occur in bone and dentine as the result of a deficient or unbalanced diet. We can watch the destructive machinery, so to say, at work. But what machinery or what destructive agents, apart from bacteria or their products, have ever been discovered engaged in the business of causing degenerative changes in enamel?

"Whatever, therefore, the future may reveal, I know of no facts at the present time on which one may base an intelligent opinion that there are either regenerative or degenerative vital metabolic activities in the enamel of fully erupted teeth.

"The demonstration through experiments on animals of the value of rational food habits and a scientifically balanced diet is one of the greatest contributions to human welfare of the present time. But this continued insistence on a theoretical proposition for which no proof is forthcoming has the effect of drawing attention away from the main significance of the work and thereby losing something of the appreciation of its real value.

* * *

"There are now a large number of facts which stand in confirmation of the statement which I made many years ago that the observed differences in the liability of teeth to decay are due not primarily to differences in structure but to differences in conditions of environment. Of course, when the environing conditions favorable to caries are present, teeth of defective structure will decay more rapidly than those of better formation.

"Mr. Malleson says in his paper, 'Further investigation of caries should show by which path the destruction of enamel takes place,' and he asks: 'Is it via prism, interprismatic substance or prism cuticle?' I think it will be clearly seen that the illustrations accompanying this article, as, for instance, Figure 72, answer Mr. Malleson's query. Decay always begins on the inner side of the rod-sheath, or what he calls the 'prism cuticle.' The appearances indicate that the acid of decay passes down along the inner wall of the rod-sheath and attacks the outer part of the rods. We see that this deeply stained area around the enamel rod begins to enlarge. A canal is formed and the area of this canal increases and encroaches more and more on the substance of the rod and the inter-rod cement-substance. As the canals continue to increase in size they become confluent, and at last the tissue breaks down and we have the commencement of a cavity. Can any one imagine any other cause for such appearances as I have shown in the illustrations which accompany the foregoing paper than the action of bacteria? . . . If metabolic changes in enamel were the chief cause of caries, then cavities might form internally or at any part of the tooth, and they would be just as likely to form on the labial surface of a tooth as elsewhere. But we all know that this is not the case. Cavities never form except at localities where bacterial plaques may form and act undisturbed. I have, from time to time, presented a large array of facts in support of the position that caries of enamel is due to bacterial action. No one, as far as I know, has ever succeeded in controverting any of these facts. All evidence in opposition to this view has been purely negative in character.

"Mr. Malleson brings forward another point which I am glad to note. He says: 'It has been suggested that the inter-columnar bridges correspond to the prickle processes seen between epithelial cells and presumably so between the ameloblasts. If this is correct, it would appear as if the ameloblast itself is calcified.' This is precisely the view that I have been advocating for more than twenty-five years. And, as may be seen in many of the illustrations accompanying this paper, it is not only the inter-rod bridges which support this view, but everywhere in the enamel rod are seen evidences of calcified protoplasmic structure.

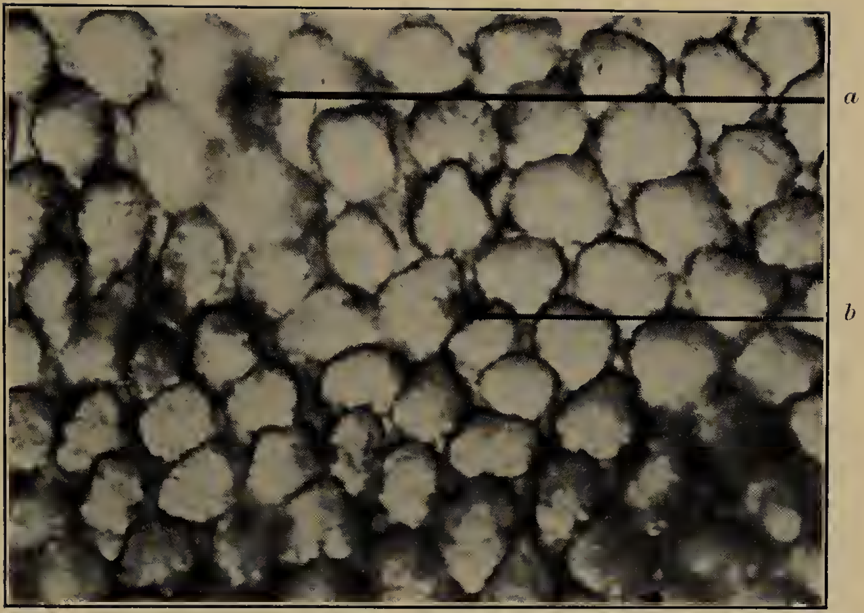

FIG. 73

Section of molar tooth from the ancient catacombs of Sicily. The enamel rod-sheath is deeply stained, and canals may be seen at *a* and *b*. The cement-substance between the rods is also clearly seen, showing that this is quite distinct from the rod-sheath.

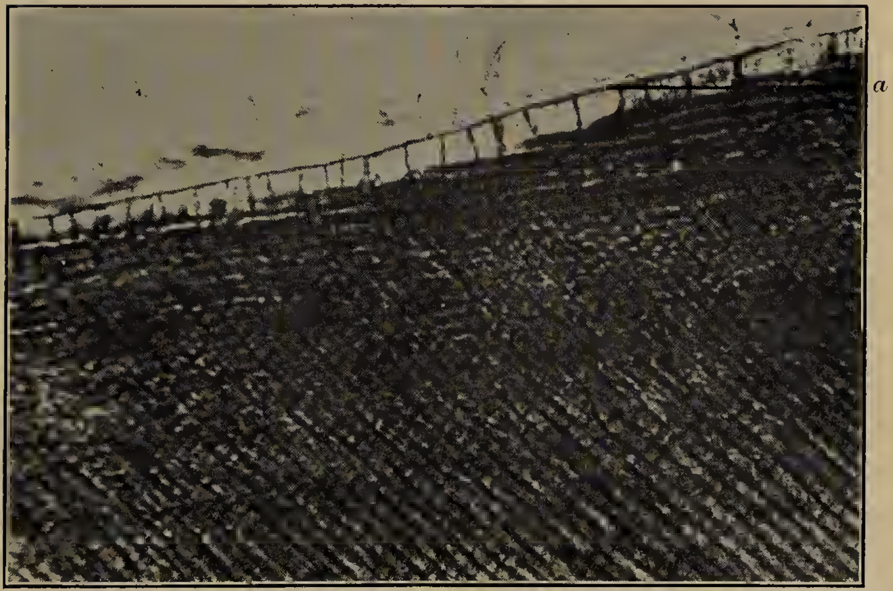

FIG. 74

Cross section of enamel nearly decalcified. *a*—Nasmyth's membrane. Connected with this membrane and passing down between the enamel rods are sections of the rod-sheaths.

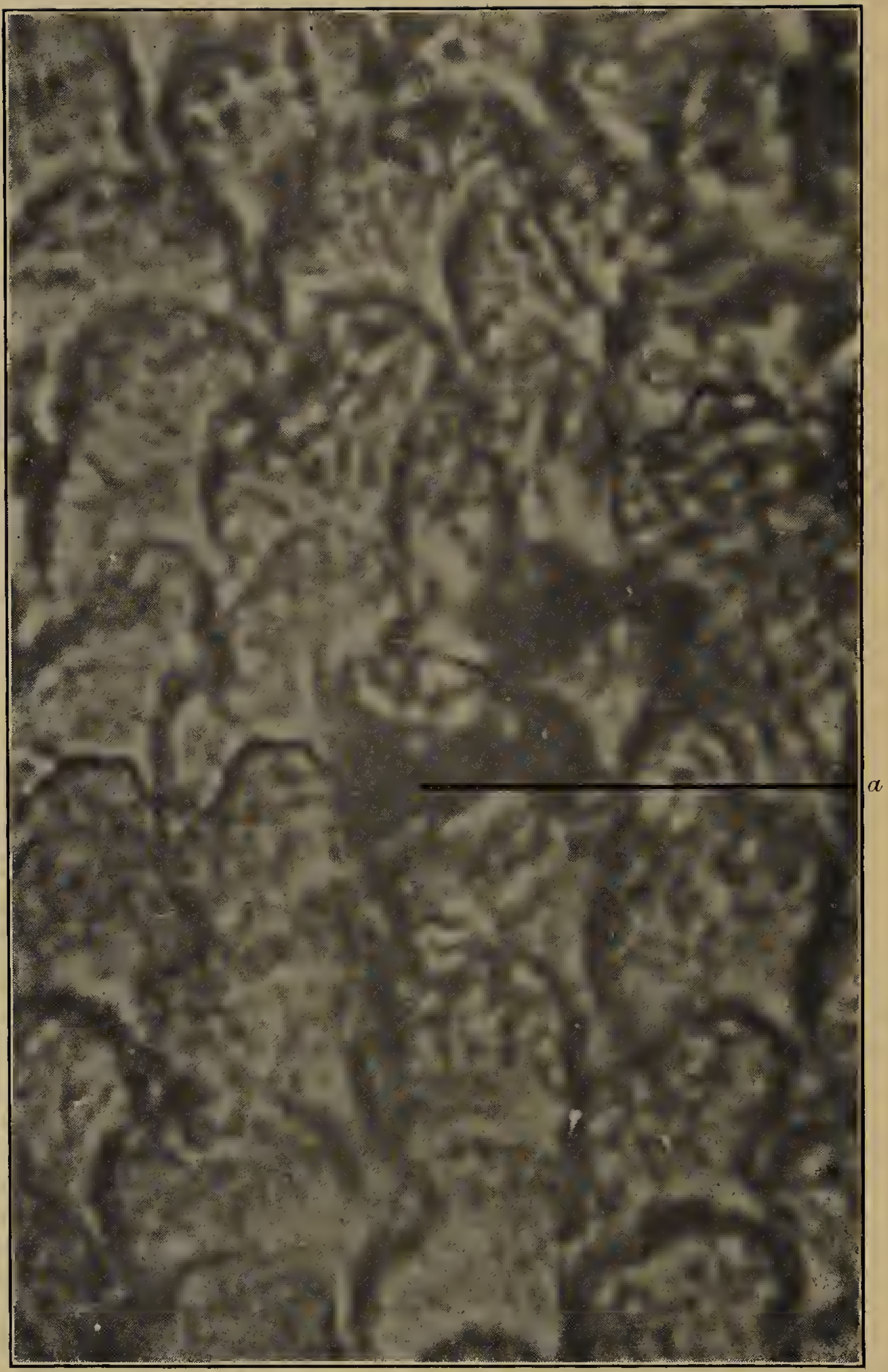

FIG. 75

Transverse section through the center of a spiral of enamel rods, magnified about 4000 diameters. The canals which are always found in the center of these spirals are shown at *a*.

"There is one more suggestion in Mr. Malleson's paper on which I will comment, and that is the difference of opinion that has been expressed as to the presence of an inter-rod substance or cement-substance in enamel. This substance is certainly present and is clearly seen in many of my photographs. (Figures 66, 73.) But the amount of this substance varies greatly in different specimens. In most forms of enamel the rods are irregularly round. Here, in the nature of the arrangement, there must be considerable cement-substance. But in some animals, the Asiatic elephant, for example, the rods are pressed so closely together as to leave but little space for cement-substance. Such a condition is occasionally seen in human teeth.

"It will be seen that on most points I am in entire agreement with the conclusions in Mr. Malleson's paper, and I hail with much pleasure the appearance of his admirable and able work."

PART THREE

THE DISCOVERY OF TYPAL FORMS IN HUMAN TEETH AND THE REPRODUCTION OF THEM IN ARTIFICIAL TEETH

PREFACE TO PART THREE

That portion of the story of Dr. Williams's achievements which is comprised in Chapters Fourteen through Twenty-one is told in a somewhat different manner from that employed in the portions that precede and follow, for several reasons:

(1) The story of the other portions of his life is the story of achievements accomplished single-handed. Much that has been related forms a part of our professional literature.

(2) There is no such record of the tremendous labors in which he has been immersed since 1910. Articles have appeared now and then dealing with different phases of the work, but they leave some of the most interesting and instructive things unsaid.

(3) Beginning in 1910, the work for improved tooth forms which Dr. Williams had carried on alone since 1906 broadened so that no one person could hope to do all that was seen to be necessary. Then Professor Gysi and the author became fellow-workers and have continued so.

Dr. Williams did, single-handed, five big things in connection with better tooth forms:

(1) He conceived a system of a comparatively few, carefully selected, interrelated forms in graded sizes.

(2) He aroused the profession to express effective interest in such forms.

(3) He discovered the typal forms in natural teeth and reproduced them and their finest modifications in porcelain teeth.

(4) He discovered and made practical a law of harmony between face forms and tooth forms.

(5) He prepared and presented to the profession such a mass of scientific evidence in support of his discoveries as to sweep away the old and unscientific

> theories and forms and to secure for the theories and forms he offered world-wide acceptance as the standards of good denture technic.

There is nowhere a coherent record from which students in the future can learn just how the revolution in tooth forms came about and how it was related to the tremendous improvements in denture technic which occurred between 1909 and 1923. The information here given will supply at least a part of such a record, for, to be complete, it should include the account of the long scientific labors of Professor Gysi, which are here merely referred to, because they form a story by themselves.

This portion of the book is largely the story of two lines of effort which joined and found themselves complementary. Much of the material from which it has been prepared is in the form of correspondence, in personal records and in memories of a thousand conversations as they have occurred in nearly fifteen years of intimate cooperation. The author tried to write the story in an impersonal way, but could not. He who through long years has been occupied in holding up the leader's hands cannot well be impersonal.

The story of every constructive life should be an account of its associations as well as of individual achievements. For obvious reasons there may appear to be a good deal of the author and others in the following section, but the intimate daily association with Dr. Williams in his Trubyte work, as well as the inevitable and necessary division of labor which threw much of the responsibility upon the author, should be sufficient explanation.

CHAPTER XIV

THE STATUS OF DENTURE WORK AT THE BEGINNING OF THIS CENTURY

IT is probably impossible for those who have entered the profession since 1914 to appreciate the depth of degradation to which plate work had fallen at the beginning of this century or how hopeless appeared the prospects of the development of a professional technic for denture service.

There had once been a group of fine technicians who made plates. They carved them from bone and ivory by laborious and tedious methods. Plate and teeth were often in one piece. We know little about how well the plates fitted, but the forms of anteriors and occlusal surfaces were often finely carved. By the middle of the last century this toilsome method had been succeeded by the use of plates swaged from gold or silver. Metal backings were soldered to the teeth, which were flatbacks. The backings were also soldered directly to the plate. There are probably not many dentists today who, even with all the modern appliances, could make an all-silver plate. But in many localities where gas and gasoline and foot or power blowpipes were unknown, dentists made these plates, using an alcohol lamp and a mouth blowpipe.

VULCANITE DENTURE-MAKING APPARENTLY EASY

The obvious difficulties involved in making all-metal dentures and the necessity for a considerable degree of technical skill at each stage deterred those who were not expert mechanics from attempting this form of service. The use of vulcanite avoided the difficult processes of swaging and soldering. It appeared to offer a simple and easy method of making dentures. It is now known that the successful use of vulcanite for dentures requires the careful application of a technic which is quite as exact and scientific as that involved in making all-metal dentures. But this was not generally recognized for more than fifty years after the first use of vulcanite and, in blissful unconsciousness of the requirements essential to the highest success, thousands of dentists who could not have made good metal dentures hopefully undertook the making of full and partial vulcanite dentures.

The Introduction of Vulcanite

The conditions surrounding the adaptation of vulcanite to denture work were not such as to produce the most desirable results. There are few left now who remember certain unhappy phases of this story, and it may be worth while to sketch the outline here in order that the younger dentists of today may realize a little of what their predecessors passed through in the development of the profession.

In 1840 Mr. Charles Goodyear was granted a patent protecting him in the process of hardening rubber by combining it with sulphur through the aid of heat. In 1854 he visited Paris and learned that Thomas W. Evans, D.D.S., had hardened rubber in a similar manner and had made artificial dentures with the resulting compound known as "vulcanite." Dr. Evans made several dentures for Mr. Goodyear. Mr. Charles Goodyear Jr. called on Dr. Evans later and was shown by Dr. Evans all of the methods which he used in making dentures. Dr. Evans refused to take out a patent, for professional reasons, and in 1855 Mr. Charles Goodyear Jr. was granted a patent in England covering all processes which Dr. Evans had developed but had declined to protect.

In America Dr. J. A. Cummings began experimenting with rubber for the purpose of making dentures, and in 1855 he applied for letters patent. His application was rejected. He withdrew his application, and it appears that at least a few dentists who could use the process made vulcanite dentures from that time on. In 1864 Cummings obtained letters patent which gave him the exclusive right of "making, constructing, using and vending to others to be used the same improvement" for seventeen years from June 7, 1864. Cummings assigned portions of his patent to different persons, among them a Josiah Bacon, who is still remembered with hatred by some of the dentists whom he hounded in the years that followed. The assignees obtained a re-issue to the Goodyear Dental Vulcanite Company in 1865.

* * *

The patentees established a system of office licenses by which they granted permission to use their methods (their patent appears to have been made to cover methods of impression-taking and model-making which had long been in common use) on payment by the dentist of a fee which seems to have ranged from twenty-five to fifty dollars. It is known that dentists paid license fees under this patent until 1881. Through the courtesy of Frank O. Sale, D.D.S., now of Urbana, Illinois, it is possible to reproduce the text of one of these licenses, showing the payment of license fee for the year ending June 7, 1881. In some cases, or for a portion of the time, it is believed that they collected a royalty of $1.00 per denture when less than six teeth were mounted and $2.50 per denture when more than six teeth were necessary. It is stated that more than 5,000 dentists took out office licenses. Many tried to evade the taking of licenses either by concealment or by defiance, but they were relentlessly pursued in the courts. Some were enjoined from making vulcanite dentures. This was a severe penalty, as 80% of the dental work in many offices consisted of plate work. Others were compelled to pay heavy damages. One dentist paid more than $1300 at one time as a penalty.

Dentists who were suspected of being negligent in the payment of royalty were often put to great inconvenience to prove their integrity. Dr. Williams was once compelled to journey from Maine to Boston to submit his office accounts to the inquisitors. Josiah Bacon was finally killed by a dentist whom he undoubtedly had annoyed a little too much.

Unscientific Denture Technic

At the beginning of this century the better forms of technic in general use in the making of vulcanite dentures were such as now appear unscientific, although certain details, which were later to be assembled into a complete technic, were being carefully developed by isolated workers in the profession. Sincere efforts were being made in some of the dental colleges to teach good denture technic, but it was almost impossible under existing conditions. Here and there individual dentists and teachers, research workers by nature, improved certain phases of the work and taught what they had learned. Among such men were Bonwill, Gritman, Snow, Walker, Christiansen, the Greene Brothers, Prothero and others. They got far less attention than they deserved, and their methods were followed by few dentists. There were none of the postgraduate courses, such as were popular between 1913 and 1923, at which practitioners could obtain instruction.[1]

Impressions of edentulous mouths were usually taken in plaster of Paris. The impression trays were mostly of heavy metal and of large size. Few dentists shaped a tray to fit the mouth even approximately. The usual practice was to select the largest tray that could be inserted in the mouth, fill it almost to overflowing with very soft plaster, get it well up or down to place and tip the patient's head forward to prevent him from being strangled by the excess plaster forced out of the tray. Some dentists even advocated building dams across the back of the tongue during impression-taking to keep the excess plaster from going down the throat. Of course, such impressions were taken with the mouth wide open—the wider the better—and with much lateral distension of the buccal tissues. When modeling compound was first used, it was placed in similar trays, in very large quantities, and with none of the attention now given to the method and extent of heating.

It is known now why such dentures often fitted well with the mouth wide open and failed to stay in place as the jaws were approximated; but in those days the question as to why dentures should loosen just as patients began to masticate was one of the bewildering and discouraging conundrums of practice. It was no uncommon event to have a patient

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[1] The first of these courses were the two taught by Professor Alfred Gysi in New York in 1913.

No. 2714

Dr. Frank O Sale

Of

Rantoul Champaign Ills.

1880

$ 50.00

Entered Folio

Entered Cash

Goodyear Dental Vulcanite Company.

LICENSE AND AGREEMENT.

Whereas, *Letters-Patent of the United States, were lawfully granted unto John A. Cummings, of Boston, bearing date June 7, 1864, for an "Improvement in Artificial Gums and Palates," of which improvement the said Cummings is the first and original inventor; and*

Whereas, *Said Letters-Patent were lawfully surrendered on account of a defective and insufficient specification, and were on the tenth of January, 1865, lawfully re-issued to the Dental Vulcanite Company, a corporation duly established in Boston, Mass., who were the lawful assignees of the aforesaid patent and invention; and,*

Whereas, *Said re-issued Letters-Patent were again lawfully surrendered on account of a defect in the specification, and were lawfully re-issued on the twenty-first day of March, 1865, in due form of law, to said Dental Vulcanite Company; and,*

Whereas, *The Goodyear Dental Vulcanite Company aforesaid, are the legal owners by assignment of the said re-issue and the exclusive right to make, use, and vend the invention of said Cummings, aforesaid; and,*

Whereas, Frank O Sale *of* Rantoul *County of* Champaighn *and State of* Illinois *is desirous of acquiring the right, privilege, or license of using the invention of said John A. Cummings, and of working the said process and using the said invention for making artificial gums, or plates for artificial teeth, according to the specifications of the Letters-Patent, above described; it being hereby expressly admitted, declared and agreed by the said* Sale *that the above mentioned Letters-Patent, under which the license hereinafter mentioned is granted and received, are valid and effectual in law to secure that exclusive right which they purport to secure.*

Now, this agreement made between the Goodyear Dental Vulcanite Company aforesaid, of the first part, and the said Sale *of the second part—*

WITNESSETH,

The GOODYEAR DENTAL VULCANITE COMPANY, *for and in consideration of the sum of* Fifty *Dollars, and the faithful performance by the party of the second part, of the conditions herein specified, doth hereby grant to the party of the second part a right, privilege or LICENSE, under the invention of said Cummings, and the Patent for the same, to use the said Invention, for the production of artificial gums, or plates for artificial teeth, in his own business as Dentist, and* for his own patients only, *and for no other purpose, and to* vend *the gums and plates thus prepared* to his own patients only, *within the said* Town *of* Rantoul *and in such other place only as there may be no located Licensee of the Company, and not elsewhere during the time for which this License is granted, upon the following conditions.—*

First. *That the said privilege or license shall not be assigned, sold, transferred or otherwise disposed of in any manner.*

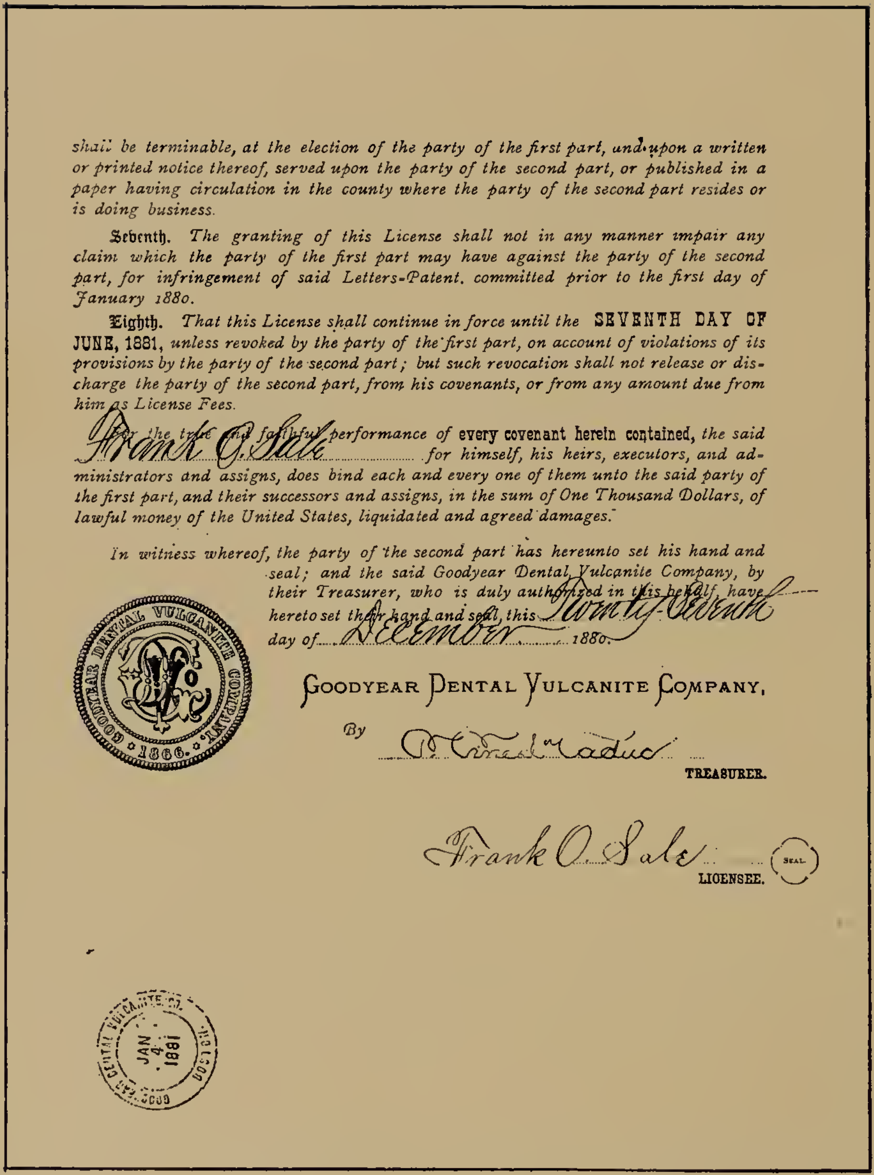
Second. *That the party of the second part shall not, by himself, his agents or servants directly or indirectly use or practise said invention, or vend said plates or gums,* for, or to other Dentists, *nor in any way, except in his own business, and for his own patients.*

Third. *That the said party of the second part shall in no manner, countenance or encourage infringements on the Letters-Patent or Invention, above described, but shall at all times recognize the validity of said Patent.*

Fourth. *That whenever said party of the second part shall furnish full and sufficient evidence, and produce the affidavits of witnesses, that any Dentist in the city or town where the party of the second part resides, is infringing said Patent, then the party of the first part shall commence proceedings against such infringing party, if he can be discovered, and prosecute the same in a reasonable manner, and by all reasonable and proper means.*

Fifth. *That the party of the second part shall not knowingly admit as a partner or employee in his business as a dentist, directly or indirectly, any person or persons who stand enjoined from the use and practise of said Invention, by the decree of any competent court; nor shall anything in this License contained, be any protection or defense to the person or persons so enjoined.*

Sixth. *That the party of the second part, for, and in consideration of the rights and privileges, herein granted, hereby covenants and agrees to hold the within granted rights and privileges subject to the terms and conditions herein specified; and that in case of failure on his part to comply with all or any of them, then this License*



shall be terminable, at the election of the party of the first part, and upon a written or printed notice thereof, served upon the party of the second part, or published in a paper having circulation in the county where the party of the second part resides or is doing business.

Seventh. *The granting of this License shall not in any manner impair any claim which the party of the first part may have against the party of the second part, for infringement of said Letters-Patent, committed prior to the first day of January 1880.*

Eighth. *That this License shall continue in force until the* SEVENTH DAY OF JUNE, 1881, *unless revoked by the party of the first part, on account of violations of its provisions by the party of the second part; but such revocation shall not release or discharge the party of the second part, from his covenants, or from any amount due from him as License Fees.*

For the true and faithful performance of every covenant herein contained, *the said* Frank O. Sale *for himself, his heirs, executors, and administrators and assigns, does bind each and every one of them unto the said party of the first part, and their successors and assigns, in the sum of One Thousand Dollars, of lawful money of the United States, liquidated and agreed damages.*

In witness whereof, the party of the second part has hereunto set his hand and seal; and the said Goodyear Dental Vulcanite Company, by their Treasurer, who is duly authorized in this behalf, have hereto set their hand and seal, this Twenty-Seventh *day of* December *1880.*

1866

GOODYEAR DENTAL VULCANITE COMPANY,

By ....

TREASURER.

Frank O. Sale (SEAL.)

LICENSEE.

JAN 4 1881

return to a dental office, take from his pocket the dentures upon which the dentist had expended his best efforts and say, "Doctor, these plates are all right except when I eat or talk."

"Mash Bites"

The methods then in general use for taking the bite or, as we now call it, "establishing central occlusion" were such as to invite unsatisfactory occlusion of the dentures. Few dentists made trial plates or occlusion rims. In most cases the bite was taken by softening a roll of wax about as large as could be easily put into the mouth, placing it between the jaws and instructing the patient to bite. There could be no control of the lateral or vertical position of the mandible. Few dentists were able to appreciate the importance of the relations to be established. It was not unusual to learn, when the dentures were finished and in the mouth, that the bite was too close or too open, or protruded or deflected laterally. An effort was usually made to correct the error by taking another bite in the same manner.

"Homemade" Articulators

Very little was known about the movements of the mandible, in comparison with what is known today, and most dentists were unaware that the articulators in general use were incapable of reproducing even the opening and closing mandibular movements. Many dentists bought strap hinges, bent them to afford room between the straps for the models and used them as articulators. Other dentists mixed an excess of plaster when pouring casts, extended each cast backward and carved one extension with a groove and the other with a ridge to form a sort of hinge, and in this way made a "plaster articulator." Probably 95% of the articulators purchased were of the plain line type. The Bonwill, Kerr, Gritman and Snow articulators were available, but were usually regarded as very complicated and were used by a comparatively small number of dentists. The importance of transferring casts from the mouth to the articulator in such way as to preserve certain relations between the casts and the articulator joint was almost entirely unrecognized.

Unnatural Forms of Artificial Teeth

The artificial teeth obtainable were of such forms as would have gone far to insure failure by the dentures if the other materials and the processes had been much better than they were. The posteriors could not be articulated, and even the occlusion was such as would not now be accepted. Dr. Bonwill tried for years to persuade dentists to articulate dentures. The obstacles against which he contended were too great to permit success during his lifetime, but his efforts entered into the general consciousness of the profession and have borne fruit continuously. He is one who, "being dead, yet speaks to us." Bonwill's labors were defeated largely because the artificial teeth obtainable in his day could be articulated only by grinding new and different occlusal surfaces. This required knowledge and skill which few dentists possessed or would acquire. When the teeth were ground to articulate in the Bonwill articulator, they frequently would not articulate in the mouth. If ground so that they articulated in the mouth, the "bite" of the molars was so deep that the plates were easily and frequently dislodged. And even if the plates stayed in position, the grinding of the occlusal surfaces destroyed the fossae and grooves essential to masticating efficiency. Truly, there was a mountain of troubles! The anteriors were conventional in form, and dentures made with them did not look much like sets of natural teeth.

Such tooth forms had come about naturally enough. The original pattern teeth either had been carved by men who were not dentists or had been copied and recopied so often that they had lost whatever naturalness they originally possessed.

There was no intelligible method by which a dentist could select either the form or the size of tooth desired for a given case. Everybody accepted the Temperamental Theory and tried to select teeth by it, but no one understood it. In probably more than a majority of cases the form, size and color of the teeth were selected by a laboratory man or a tooth clerk who never saw the patient.

Conventional Forms of Anterior Teeth

The forms of anterior teeth offered by the leading manufacturers were conventional and unnatural in appearance and chaotic in their unrelatedness to one another. There was no law of harmony between face form and tooth form, and dentists could select only by going over the list of moulds and choosing what pleased the eye. It resulted that many dentists used three or four moulds for all cases. One dentist who had an enormous plate practice used Twentieth Century Mould 14, Shade 4, for all cases. There was usually only one size in one form. If a dentist found the desired form but it was in the wrong size, he had to grind it to size or select another form of a size that he could use.

Public Esteem of Artificial Dentures

Public appreciation of denture service was very low, but probably fully as high as the average grade of service justified. Most of the plates did not fit when made, and most that came to fit did so because nature shaped the tissues to fit the dentures. They were not generally pleasing in tooth forms and arrangement. Dentists and patients developed a fondness for very white teeth, and in many cases a person seen at a distance with the lips parted could be identified as wearing artificial teeth before the features could be distinguished. The public expressed its appreciation by the only term it then accepted—"false teeth."

Fees for Denture Service

Fees for denture service were unremunerative to dentists and insufficient to purchase good service if such service had been possible. For half a century or more there had been unintelligent price competition among dentists. The fees varied in different localities and in different offices, but it is probable that the average fee for a full upper vulcanite denture was not much in excess of $10.00. Many dentists habitually made them for $7.50. For this sum, at least in some offices, the dentist extracted whatever teeth were necessary, sometimes as many as twelve or fourteen, using a local anesthetic and taking pains to make a favorable impression on the patient in order that he might be selected to make the plate. He then waited a few weeks to permit resorption of the gum tissues, made the denture and struggled with the patient to make it satisfactory by grinding or by argument until dentist or patient "gave in." Up to 1900 the more conscientious dentists paid about $2.00 per 1x14 for platinum-pin teeth. It is obvious that if the dentist extracted a few teeth, paid $2.00 for artificial teeth and made a denture for $10.00, he received very little for his labor, especially if he had to refit the plate two or three times or remake it. An investigation of 100 such dentures, made about 1915, showed that two in every four such dentures had to be made a second time and that one of the remaining two should have been.

Industrial Dental Laboratories

To complicate the situation further, there grew up a group of what are now called "industrial laboratories" which offered to do all of the mechanical work of denture-making for the dentist except take the impression and bite. Sometimes the laboratories were conducted by dentists, sometimes by men who knew nothing about dentistry. These laboratories found a welcome reception and numbered among their patrons dentists by thousands. Some of them flooded the country with advertising, soliciting business on the basis of low prices. If a dentist would send impressions and a bite, the laboratory would set up a full upper and lower, furnish the teeth of some of the less expensive qualities, return the plates for try-in, wax, vulcanize and polish the two dentures for $6.00.

The facility of laboratory service was sometimes ruinous to the exercise of what little skill the dentist necessarily would have applied to impression- and bite-taking if he had done his own work. A large proportion of the impressions and bites sent to the laboratories would have disgraced a freshman in any dental college. They were such as no dentist, in possession of his senses, would have thought of using if he were to complete the work himself, a condition by no means entirely rectified as yet. Some laboratory men developed uncanny skill in making dentures under such conditions. Directions by dentists as to what should be done were often hazy or wholly lacking. The selection of the shape, size and shade and the arrangement of the teeth were often left to the laboratory. One such industrial laboratory received a roll of wax which had been flattened on two opposite sides. On each flat surface could be traced a shallow, irregular and poorly defined depression. The order read: "Use this wax as impressions and bite. Make full upper and lower for a fat woman forty-five years old." When the manager of the laboratory wrote to the dentist that the depressions were too incomplete to permit making dentures that would be at all satisfactory, the dentist withdrew his patronage from that laboratory because, in his words, "they didn't know their business."

❦ ❦ ❦

In the face of such a wide range of adverse conditions it is not surprising that the failures in denture cases greatly outnumbered the successes. Dentists became discouraged because, when they chanced to succeed, they did not know why they had succeeded and so could not improve their technic. When they failed, they usually did not know why they had failed or how to find out what caused the failure. Many of the more conscientious dentists discontinued full denture service. Fixed bridgework attained a tremendous vogue.

A Movement to Divorce Denture-Making from Professional Practice

So deplorable did the conditions surrounding denture work become that during the early years of this century there grew up, at least in certain sections of the country, a strong sentiment in favor of divorcing that service from professional dentistry and leaving it to the mercy of anyone who cared to practice it. This was referred to by Dr. Norman W. Kingsley, one of the prominent dentists of his time, as follows:

"In these days of the advanced and scientific state of modern dentistry it is about as much as a man's reputation is worth to refer to mechanical dentistry. I think those who have listened to the discussions upon the subject of dental education in the various State and National Societies, and have read the immense amount of nonsense that has been written on that subject, must have become disgusted if they have ever had any interest or pride in artificial dentistry. It must be quite fresh in your minds that for some little time there has been a movement in certain parts of this country to divorce the two branches of dentistry from each other and to teach scientifically only one department—that relating to operations on the natural teeth—in dental colleges and to relegate everything that belongs to artificial dentistry to the carpenters and blacksmiths, as something that is beneath consideration and entirely too undignified to be made part of a college curriculum. I think the worst punishment that I could inflict on such men, if they should lose their natural teeth (as some of them certainly will do if they live long enough), would be to compel them to wear a piece of artificial dentistry made with their own fingers."[1]

Recognition of Need of a Revolution

Dr. Williams was thoroughly familiar with all these conditions and some others which it is not necessary to mention here. He entered the profession while plate work formed a large part of dental practice, especially in country places. He had learned by observation and experience to trim and shape impression trays to fit mouths and to trim the casts. He improved his impression technic by boring holes in the palatal and ridge surfaces of trays to permit the escape of the excess compound when he took the first impression. This served as a tray for a plaster impression in the method now so extensively practiced. Then he came, as did other dentists, to the wall that barred progress: the teeth he purchased at the depots could not be used to make dentures that satisfied him. He believed that if teeth could be provided that were natural in appearance and capable of articulation, hope would spring anew in the professional heart, many of the problems of technic would be solved by other workers, patients would receive much better service, denture work would take its proper place in public esteem, it would be possible to obtain remunerative fees when they were deserved, and the professional standards then dragging so heavily in the dust could again be held on high.

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[1] Remarks before the New York Odontological Society in 1906.

As Dr. Williams's conception of the work developed, there gradually grew up in his mind the great perception that the designing of tooth forms and sizes should not be left to the tooth manufacturer, who, presumably, knew nothing about the conditions under which the dentists must use teeth, but that teeth should be designed by dentists. In other words, the profession should find out what it needed and specify that to the manufacturer. He set himself to arouse his fellows to this perception, and he has lived to see a greater degree of success attend his effort than is accorded to most workers for the common good.

CHAPTER XV

DR. WILLIAMS'S EARLY EFFORTS TO SECURE BETTER ARTIFICIAL TEETH

DR. WILLIAMS made his first effort to obtain better forms of artificial teeth about 1902, at which time he suggested to the Odontological Society in London that if artificial teeth were better made, they could be more easily and more efficiently used, with great benefit to patients. He believed also that through proper representations by the dental profession the manufacturers could be persuaded to produce better forms. His suggestion was noted, but nothing came of it.

Dr. Williams was deeply impressed with the importance of denture work for edentulous patients and with the obligation resting upon the profession to make dentures that were natural in appearance and efficient in mastication. He knew that practically no artificial dentures of that day met these requirements. He knew why, because he continuously found his own best efforts to secure pleasing appearance nullified by the conventional forms and chaotic sizes of the teeth obtainable at dental depots and his efforts at articulation thwarted by the forms of the occlusal surfaces.

He knew also that if artificial denture service were divorced from professional dentistry, it would be an acknowledgment that the profession could not solve its own problems. More serious—it would be a professional retreat where professional salvation required an advance. And he felt sure that if the retreat were made, the profession would sometime have to acknowledge its error and recover the lost ground. The longer the advance was delayed, the more difficult it would be.

DR. WILLIAMS'S PLEA TO THE MANUFACTURERS

As no one else seemed disposed to begin the activities likely to result in the production of better teeth, Dr. Williams resolved to act alone. In 1905 he appeared before the Board of Directors of one of the firms manufacturing artificial teeth in England and pointed out the serious defects in teeth, the superfluity of many of the moulds and the complete lack of scientific system. He then made a plea that the company should undertake the production of tooth forms better suited to permit a satisfactory quality of plate service by dentists. The directors listened with attention and respect. At the close of his plea the chairman, speaking for the Board, replied in practically these words, "We have heard with interest all that you have said and we think that perhaps the improvements you suggest are possible and desirable. The dentists who purchase 90% of the teeth appear to be satisfied with the tooth forms as they are. The number who would pay for the improvements you desire is too small to justify any manufacturer in undertaking the very large expenditure which he would be compelled to risk."

CONDITIONS WHICH PREVENTED PRODUCTION OF BETTER TEETH

Since the chairman expressed or implied at least five conditions of long standing against the inertia of which Dr. Williams was to struggle for a number of years, it will be worth while to set them forth as they existed in America at least.

(1) By far the largest quantities of teeth were purchased by industrial laboratories and advertising dentists. These purchasers appeared either satisfied with the existing forms or indifferent to improvements. Other dentists who made plates and felt their own professional responsibility grumbled at the forms and sizes but, with few exceptions, made no suggestions which were constructive in sufficient detail to carry a conviction of merit or permit being acted upon.

(2) The dental profession, in general, was apathetic on the subject of tooth forms and sizes. Many dentists, especially in large cities, no longer made artificial dentures. If there ever had been good tooth forms, few

dentists were old enough to remember them. There never had been a sufficiently scientific denture technic to insure even a reasonable proportion of what would now be called denture successes. Failures in denture service greatly outnumbered successes, and artificial dentures were usually a source of continuous trouble to dentists as well as to patients. Fees were low and were being further lowered by dentists who sold plates about as they might have sold shoes; that is, they took impressions and bites, hired the plates made and fitted them to the patient, or the patient to them, as best they could. They frequently charged only a commercial profit over the laboratory's fee.

(3) No one knew in what way tooth forms should be improved. Dr. Williams had made his first appeal with the thought that the manufacturers would know what to do and how to do it; but no one knew how to begin to find out. The conception that was later to dawn on one of his coworkers, that no man can produce scientific tooth forms unless he is experienced in the scientific use of artificial teeth, had not made itself known. And so he had not prepared a definite campaign of improvements to suggest to the directors before whom he appeared.

(4) The manufacturer who would offer improved forms of teeth was confronted with the necessity of a very large expenditure of money before he could know that the improved teeth would meet with the approval of the profession. Not only must he undertake the initial expense of finding out what was required, but he must supply stocks of teeth to the dental depots in sufficient quantities to make them available to the profession. If the teeth were not approved by the profession, the money loss might easily be disastrous to the manufacturer.

(5) The manufacturer could not obtain satisfactory patent protection for the new forms to insure to him the exclusive sale of the improved teeth long enough to enable him to reap a reasonable profit as the results

of his labors and expenditure. After he had done all the preliminary work and established a market, any other manufacturer might immediately copy the new forms without initial expense and risk. The original manufacturer had only this protection, which was not so fully understood then as it is now, that one cannot successfully copy artificial teeth so that they will be equal to the originals.

* * *

When the directors of the English company told Dr. Williams that no tooth manufacturer could afford to risk the very large sum of money necessary to effect the improvements he sought, he concluded that improvements in artificial teeth would result only from the intervention of much more powerful agencies than he could arouse; so he turned his attention to other interests.

Dr. Williams Aroused by Dr. Spence

In the meantime, similar perceptions and convictions as to the need for better tooth forms had been developing in another mind. The *Items of Interest* for August 1907 carried an appeal from Dr. Stewart J. Spence of Chattanooga, Tennessee, U. S. A., for improved forms of artificial teeth. This was the clarion call to reawaken Dr. Williams's interest. He determined to revoice his presentation to tooth manufacturers, to secure the collaboration of leading prosthetic dentists in offering a definite program of improvements and to obtain from members of the profession throughout the world such an expression of interest and desire as would justify tooth manufacturers in undertaking the labors and expenditure necessary to produce better forms of teeth.

The Appeal Through the Items of Interest and the Response by the Profession

In the *Items of Interest* for November 1907 there appeared an urgent communication from Dr. Williams asking for united action by dentists to obtain better teeth. The following brief excerpts from this article are of interest:

"Let us begin with the occluding or articulating surfaces of the teeth. These surfaces, as presented today in all artificial teeth that I know anything about, are simply utterly foolish. There is no other expression that fits the situation. They are utterly foolish, and the efficiency of artificial teeth is diminished one-half by this foolishness. . . .

"With reference to the number of moulds required, I have for years maintained that ten types of teeth with about six sizes for each type would, *if the types were carefully studied,* give us a far better selection of teeth than is now presented by all the moulds of all the manufacturers combined. . . . A card of teeth showing the different types and sizes and a good assortment of shades would place the dentist in a better position for selecting exactly what he needs than he now is when standing before the largest stock of teeth carried by any firm. It is simply astounding that in the United States, where scientific methods are so much talked about and where time is considered such an important factor in business, something of this method has not been thought of before.

* * *

"I do not know how many moulds of teeth the different manufacturers are represented by, but I have no doubt there are several thousands on the market. What a waste of time and money! What a systemless system! One manufacturer offers teeth from five hundred moulds. Another manufacturer offers five hundred more quite different. None of them are based on careful artistic studies of temperamental types of natural teeth. The profession has no voice in the matter—it takes what is offered. And the teeth that are offered bear about the same relation to what we should have, from the artistic point of view, that the illustrations in a fashion magazine bear to the portrait work of an artist of repute. . . . In the meantime, I ask all who are interested (and that should mean every reader of this communication) to write, if only a postcard, to Dr. Ottolengui expressing views and desires, and I especially ask all who are willing to assist in the undertaking by taking impressions and making models of fine sets of natural teeth to indicate this in their letters. The response to this appeal will indicate just where we stand as a profession on the subject of dental prosthesis."

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If the response indicated where we stood on the subject of dental prosthesis, it appeared to justify the statement of the manufacturers in London two years before. Out of more than 50,000 practicing dentists in the English-speaking world, only three wrote to Dr. Williams. They were: Dr. Alfred Gysi, Zurich, Switzerland; Dr. L. P. Haskell, Chicago; Dr. Booth Pearsall, England. After that nobody moved. Apparently the profession in general did not care enough about better tooth forms even to write postcards in their behalf.

THE EDITORIAL BY DR. OTTOLENGUI AND THE RESPONSE BY THE PROFESSION

In the January 1908 issue of the *Items of Interest* Dr. Ottolengui wrote a strong but somewhat pessimistic editorial on the subject, of which the following is an extract:

"From time to time some student of the subject points out how poorly suited to the proper mastication of food are dentures composed of the artificial substitutes supplied by our tooth factories, and the manufacturers are held responsible for the badness of the moulds. In our November issue we published a communication on this subject from Dr. J. Leon Williams. Dr. Williams pointed out that it is next to impossible to reproduce normal occlusion with the porcelain teeth purchasable at dental depots. Dr. Williams also asked for an expression of opinion from the dentists of the world as to the desirability of changing the prevailing forms of tooth moulds. In the December issue we did not touch on this subject, thinking perhaps that between the date of publication of the November issue and the date of sending the December number to press there had not been time enough for dentists to write the requested opinions. Now, however, more than seven weeks have passed.

"It is estimated that there are more than thirty thousand dentists in the United States, the majority of whom, of course, to some extent furnish their patients with artificial teeth. Not one of these has responded to Dr. Williams's letter by writing to us. From a private letter we learn that Dr. Williams himself has received three replies. . . . Where, then, is the evidence, commercial evidence, that there is any demand for new moulds?

"Anyone who has studied the articulating of artificial teeth, in accordance with the rules set forth by Bonwill, will admit that the artificial teeth carried in stock are woefully wrong in shape. To fashion a complete upper and lower denture, setting the teeth with the assistance of an anatomical articulator, the dentist must grind every tooth, especially the morsal surfaces of bicuspids and molars. This not only destroys all semblance of cusp formation, but removes the surface glaze from the porcelain and renders cleanliness just so much more difficult. Moreover, the labor involved and the time required make this practically prohibitive, except for very high fees. The writer once kept accurate record and found that he had spent eleven full hours in articulating an upper and lower denture.

"There is no disputing this argument, but it is hardly one that will appeal to the manufacturers. Tooth makers, like the makers of any other object of barter, can only be expected to regulate themselves by the laws of supply and demand. A style in hats, gloves, clothing, furniture, glassware, breakfast food or any other salable article will be adhered to just so long as the maker finds sale for his product, and no longer. The more enterprising merchant may endeavor to set the fashion, to originate a new style and to create a new market for an improved article; but he will do this only if there appears to be a demand for a change. It is not different, and cannot be different, with artificial teeth. The dealers will not consider the commercial proposition of making new moulds, and producing new tooth forms, until the demand for the change is manifest among dentists who buy and use their products.

"Supposing, then, that the dentists of the world should show some interest in the subject, and supposing that it should become evident that new forms of artificial teeth are desired, it must become the task of the dentist himself to dictate just what this new shape shall be. This is an Herculean task, but it is one to the solution of which Dr. Williams seems willing to bend his energies. But Dr. Williams is somewhat in the same position as the tooth manufacturers. Why should he undertake this work for some fifty thousand dentists, only three of whom seem sufficiently interested even to write a letter commending the enterprise? Why should Dr. Williams give months of toil to the study of tooth forms merely to lighten the labors of the dentists? Why not allow the dentists to grind porcelain teeth, as heretofore, needlessly for hours, if they prefer that to the labor of either helping, or at least encouraging, Dr. Williams and the tooth makers to produce teeth which can be made to simulate normal occlusion without so much grinding?

"Let us, therefore, ask the members of the profession in this country, 'Do you desire an improvement in the shapes of porcelain teeth? If so, please write us your views. Tell what is required.' "

* * *

Dr. Ottolengui's editorial and letters from Dr. Williams in the February and March issues brought to the *Items of Interest* replies which were published as follows: five in February, ten in March, four in April, seven in May, four in June, two of which were from societies and so represented more than one dentist. After that—not a word! Probably the *Items* reached at least 15,000 dentists monthly; 2/10 of 1% of them signified an interest in a subject of major importance to themselves and their patients. And as soon as Drs. Williams and Ottolengui took off their personal pressure, the issue dropped, apparently as dead as it had been before they began.

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In the March 1908 issue of the *Items of Interest* Dr. Williams sought to correct a misconception, in the following words: "Some of my confrères seem disposed to lay the blame for the present defects in artificial teeth entirely at the doors of the manufacturers. With that proposition . . . I do not entirely agree. . . . I have no hesitation in saying that far greater benefits to our profession have resulted from the enterprise of manufacturers than have ever grown out of any collective or cooperative action of the profession itself. . . .

"If one hundred prominent dentists were to sign a request for any definite thing wanted it is altogether probable that any of the leading manufacturers would spend any reasonable sum of money and make any reasonable effort to supply that demand. Now, it should not be a difficult thing to get one hundred times one hundred dentists to sign a petition for improvements in artificial teeth."

An Appeal to the National Dental Association

At the twelfth annual meeting of the National Dental Association, Boston, Massachusetts, in 1908, an appeal from Dr. Williams for concerted action by dentists to secure better teeth was read by Dr. E. S. Gaylord.[1] The appeal covered four points, as follows:

(1) Occlusal surfaces modeled after the occlusal surfaces of natural teeth.
(2) Incisors formed like natural teeth.
(3) Better gradation of coloring in natural teeth.
(4) Related forms and graded sizes to facilitate selection.

Apparently no action on this appeal was taken.

Why Improved Tooth Forms Could Not Then Be Produced

Sixteen years have passed since these efforts were made, and many things not known then are known now. The manufacturers could not improve the forms of teeth because they did not know in what the improvement should consist. They were commercial men, who understood manufacturing, but they knew practically nothing about the use of teeth by dentists in making plates, and without that knowledge they could not possibly know what forms teeth should exhibit to meet the dentist's needs. The members of the dental profession could not tell the manufacturers what the forms of teeth should be because they did not know. Even Dr. Williams didn't know! And, as will be seen if one reads far enough, when he got his chance to produce the forms he wanted, he had to learn, first of all, what those forms should be. After two years of intensive study and carving he found the theory on which anterior tooth forms were based so seriously mistaken that he had to discard much that had been done and start anew.

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[1] *The Dental Cosmos*, 1908, page 1383.

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The determination of tooth forms, sizes and colors never was a suitable task for commercial men engaged in making teeth. It was always a task for the profession. The profession, as a whole, appears never to have undertaken it and certainly never did it. Individual dentists here and there labored for years at the problem and made interesting observations, but these were never correlated into a system. They were founded on unscientific theories or assumptions which ended in confusion and failure at every effort to apply them.

A knowledge as to what constituted proper forms and sizes in teeth was never obtained until the financial support of a far-sighted tooth manufacturer made it possible for certain dentists to give up all other forms of occupation and devote years of intensive study and experimentation to the problems involved. And the very first problem of all was to find a scientific foundation on which to work.

CHAPTER XVI

Definite Steps to Produce Better Teeth

THE last letter written by a dentist to the *Items of Interest,* in response to the appeal of Drs. Williams and Ottolengui, appeared in the issue for June 1908. There were probably 40,000 dentists practicing in the United States. In the period of six months during which this subject was kept very much to the fore in that magazine about one dentist in every 1200 in practice manifested sufficient concern in this important subject to express approval in writing.

The Degree of Constructive Interest of Those Who Replied to Dr. Williams

An interesting side light was thrown on the degree of interest shown by those who wrote and the extent to which they were prepared to support their words by constructive acts. At the time the letters appeared, the author was engaged in efforts to influence certain American tooth manufacturers to produce better teeth. As each letter appeared in the *Items of Interest,* the author wrote to its writer asking whether he would be willing to carve one or more teeth expressing his conception of one or more improved forms, in order that they might be submitted to an American tooth manufacturer. He offered a supply of the little plaster blocks such as tooth-carvers use and an articulator with the casts ready mounted and fitted with wax baseplates. Thirty-two of those addressed took no notice of the communications. One said that he would carve one or more teeth. The blocks, articulator and casts were sent to him. About two years later the package was returned. Apparently it had never been opened.

In the summer of 1908 the author called upon Dr. Williams in London. The two workers encouraged each other in the worthwhileness of the undertaking, but neither had then accomplished anything sufficiently definite to be of more than general interest.

DR. WILLIAMS APPEALS TO PROMINENT DENTAL DEALERS

Dr. Williams waited from June 1908 to June 1909 for some further indication of interest by dentists generally in the matter of better tooth forms. Not a ripple disturbed the quiet waters. In the summer of 1909 Dr. Williams persuaded the heads of the firm of C. de Trey and Company of London, England, that improvements in tooth forms not only were possible and desirable but were practicable and would be profitable to the manufacturer who offered them. Through their intercession The Dentists' Supply Company of New York sent to London its most accomplished tooth-carver, who worked with Dr. Williams during a portion of the summer and carved one or two sets of teeth according to Dr. Williams's directions.

As a result of this experience, Dr. Williams formed these convictions:

(1) That he must personally carve new forms or at least supervise the carving.

(2) That he must visualize more definitely what he desired and devise some plan to make it possible for manufacturers to see just what was wanted.

(3) That the best way to show the manufacturers was to carve specimen sets of teeth so far superior to the current forms as to inspire the belief that they could sell enough of the improved teeth to justify the risk incurred in introducing them.

DR. WILLIAMS LEARNS TO CARVE TEETH AND TAKES THEM TO AMERICA

He selected two or three of what he considered the finest forms of natural maxillary anteriors, familiarized himself with their characteristics in minute detail, applied every hour that could be taken from practice to mastering the art of carving plaster teeth and, in a few months, produced several carvings of much finer character than the current forms in porcelain teeth. Fortified with these as a demonstration of what could be done, he arrived in America about the first of November 1909 with these purposes in mind:

(1) To arouse members of the profession to an expression of interest sufficient to persuade or compel the manufacturers to produce better teeth.

(2) To confer with other dentists and by united action complete the specifications of forms and sizes required.

(3) To convince tooth manufacturers that the production of such teeth would be profitable.

(4) To open the gateway to improvements in many other details of plate work by persuading the profession that denture service could be made satisfactory to patients and profitable to dentists. His own experience proved that there were many persons desirous of obtaining such service and willing and able to pay well for it.

A Proposed System of Forms and Sizes

An element of Dr. Williams's plan which is generally overlooked, but which is of great importance, is that he wanted a *system* of tooth forms and sizes. Not only were the individual forms to be made more natural in appearance, but they were to be so carefully selected from the multitude of forms of natural teeth that a comparatively few of them would afford at least approximate matches with the most frequently seen forms in natural teeth and be capable of modification by dentists to match many more forms. There were to be several sizes in each form and an interrelation of sizes between related forms. This part of Dr. Williams's plan was more revolutionary than his proposal for new individual forms. It broadened the scope of the project, it greatly increased the financial risk of the manufacturer who should first introduce it, and it was, for a time, the greatest obstacle to the acceptance of his plan by a manufacturer. This is particularly interesting in view of the fact that every tooth manufacturer of prominence has now copied this plan, wholly or in part.

Dr. Williams looked forward to a world-wide revolution in tooth forms. He knew this to be possible only if one of the great manufacturers should undertake the work. And so, long before this visit to America, he began a careful observation of the tooth manufacturers of the first rank, the quality of their porcelain and shades, their attitude toward improvements in their products and the sales organizations through which goods were made available to dentists.

The Attitude of Tooth Manufacturers

Immediately after his arrival in America Dr. Williams laid before the leading American tooth manufacturers the elements of his plan. In most instances he found one or more of four well-defined attitudes of mind: (1) an utter lack of knowledge as to what changes in tooth forms were possible, practicable or desirable; (2) an awareness that few dentists had responded to Dr. Williams's letters in the *Items of Interest* and a conviction that at least the dentists who purchased most of the teeth were fairly well satisfied with the current forms; (3) a willingness to produce a few new moulds of teeth, if Dr. Williams would sponsor them to the profession, but no understanding of a system of forms and sizes; (4) hesitation at undertaking the great expense necessary to the production of an entire new system of teeth, partly because it was impossible to obtain adequate patent protection.

Constructive Activities by One Manufacturer

Dr. Williams found one company prepared to understand his proposition because it had, for some years, given much attention to improvements in teeth and had begun activities which were later to prove to be the first steps in the educational campaign that was an important part of his plan. This was The Dentists' Supply Company of New York.

From the date of the organization of this company in 1899 it had offered a superior quality of porcelain. In 1900 it introduced soldered-pin teeth for vulcanite plates and enabled dentists to purchase teeth of superior appearance and strength for less than half the price of platinum-pin teeth, a most important item to thousands of dentists who habitually received the low fees for plate work then current.

In 1906 the Company established a Research Division, under the direction of a dentist experienced in plate work, for the purpose of ascertaining in what ways the teeth which were its sole product could be better adapted to the dentist's needs. In 1908 it published an improved method of selecting sizes of artificial teeth by means of millimeter measurements. In March 1909 it offered Twentieth Century anatomical moulds in bicuspids and molars. These teeth, the first real improvement in tooth forms in a generation, found immediate favor with the profession because they could be easily arranged, they articulated well and they contributed materially to the stability and efficiency of artificial dentures.

The Research Division correlated elements from the writings of prominent prosthetic teachers, including Bonwill, Walker, Christiansen, Snow, Prothero and others, into a relatively simple system for securing anatomical articulation in artificial dentures. Representatives of the Division gave lectures and clinics in the exhibit spaces taken by the Company at dental meetings. These were thronged by dentists and did much to arouse interest in better denture technic.

A Story by Dr. Black

The technic taught in these clinics was improved as the result of suggestions by many dentists. At the meeting of the G. V. Black Club in Minneapolis Dr. C. N. Johnson, in passing, saw the clinic and grasped the essential points. He then hunted up Dr. G. V. Black and brought him to it, with the expression: "Here is a sorely needed improvement I want you to see." Dr. Black listened to the explanation, examined the models and dentures, then said: "That is an excellent thing. I hope it will arouse great interest. There is one step you might add. When I was making myself a lower denture and had difficulty in getting it to fit the upper, I put emery powder and vaseline on the occlusal surfaces of the lower teeth, put the denture in my mouth and ground it to articulation." From that day on, the "grinding-in" of dentures by the use of an abrasive was part of the technic.

In the summer of 1909 the Division prepared for publication a book entitled *The Mechanical Side of Anatomical Articulation* (now out of print). This was published early in 1910. Twenty thousand copies were circulated, and they undoubtedly aided in extending interest in the subject of better artificial dentures.

THE REVOLUTION PROPOSED BY DR. WILLIAMS

The plan which Dr. Williams outlined to the Company was so extensive and revolutionary as to require the most careful consideration. It contemplated a considerable period of study to determine the details, the production of an entire new system of teeth and the investment of a large sum of money to provide stocks of teeth for the depots, with the probability that if the new teeth proved as popular as Dr. Williams anticipated, the current forms of teeth, of which there were great stocks in the dealers' hands and in which the Company had a big business, would be displaced and the very large sum of money invested in master patterns, working moulds, etc., for making those teeth would be mostly or wholly lost.

FORMER EXPERIENCES IN PRODUCING IMPROVED TEETH

Certain experiences of the Company in producing new moulds inspired a natural hesitation on the threshold of a venture in which so much must be risked before there could be any assurance of success. Other dentists, quite as experienced in plate work and as enthusiastic as Dr. Williams, had persuaded the Company to produce moulds which they believed to be great improvements upon the current forms and which they felt sure the profession would welcome. The Company had manufactured the thousands of sets of teeth necessary to stock important depots. Lectures and clinics, illustrating the use of the teeth and describing their advantages, had been given just as Dr. Williams proposed that they be given. But apparently no dentist would buy these teeth a second time. Some idea of the loss by the manufacturer may be formed from the fact that one depot kept a stock of these teeth for several years with no sales and then returned, at one time, 3600x14. There was no market for them, and they were destroyed. The one ray of hope which encouraged the Company to consider Dr. Williams's plan lay in the cordial reception which the profession had extended to the Twentieth Century anatomical moulds.

AN AGREEMENT WITH DR. WILLIAMS TO PRODUCE A SYSTEM OF STANDARDIZED TEETH

The reason why there could be no certainty in advance as to the popularity of new forms lay in the fact that no dentist or group of dentists had authority to speak for the entire profession. There was no professional tribunal, such as had been recommended by Dr. Williams in 1899, before which such matters could be brought and by which the combined wisdom of the profession could be expressed. More fundamental yet—no one at that time knew what forms should constitute a system of teeth. But the Company was willing to take its share of the risk in finding out, and in December 1909 it made an agreement with Dr. Williams that if he would secure from the rank and file of the profession satisfactory evidence of interest in a determined effort to improve the forms, it would produce the system of artificial teeth which he proposed. This agreement was particularly pleasing to Dr. Williams because he had decided, before leaving England, that he should greatly prefer to have this company bring out the teeth.

COOPERATION WITH PROFESSOR GYSI

Hardly had this agreement been completed when the January 1910 issue of *The Dental Cosmos* brought to the profession the first of Dr. Gysi's epoch-marking articles, *The Problem of Articulation.* Here was a possibility of assistance in deciding upon the desired forms. Dr. Williams remained in New York only long enough to perfect his plans for cooperation with the Company and then started for Zurich, where Professor Gysi lived. He laid his plans, as far as they had been formulated, before Professor Gysi, whom he knew from previous correspondence to be interested in the campaign for better tooth forms, and the beginnings of an understanding as to cooperation were reached. Dr. Williams then returned to London to continue his studies of tooth forms.

He was now face to face with some of the most difficult decisions in the whole course of the work. What forms should be selected for the system? They must be few in number but must meet a multitude of needs. He was compelled to concentrate on details which would be unthought of by anyone not engaged in the production of teeth. What should be the relative lengths and widths in the different forms of centrals? How wide should the laterals be, in proportion to the centrals, in different forms? How wide should the cuspids be in proportion to both? What sizes would be most serviceable? What should be the thickness? How long should the bite be to meet with the approval of different groups of workers? His solutions could not be purely theoretical. He had to take into consideration the degree of skill in denture technic and the more advanced skill to which dentists could be persuaded.

CHAPTER XVII

"THE ESTHETIC AND ANATOMICAL BASIS OF DENTAL PROSTHESIS"[1]

DR. WILLIAMS was unable to spend as much time in technical studies as was desirable because it was an essential part of his contract that he should obtain from the "profession at large" evidence of its interest in improved forms of teeth. There was a reason of no small importance to Dr. Williams and the Company why this approval should take just this form. It had been quite easy for Dr. Williams to secure this form of approval from a number of dentists in and around New York who might be called "leaders in the profession." But these dentists made few or no plates. They would buy few or no teeth, no matter how much they might be improved. And their approval, while important, was purely academic. Both Dr. Williams and the Company needed evidence of interest from the dentists who were making plates and who would be possible and probable customers for better teeth.

Dr. Williams was therefore compelled to sail from London so as to reach America in June 1910. On July 19th he delivered the address which follows. At this time he was seeking merely to obtain from the profession such evidences of interest and desire as would justify the continuation of the work.

"The esthetic standard of dental prosthesis is primarily determined by the artistic quality of the porcelain teeth used, and a correct anatomical basis demands that these teeth should be so shaped that correct anatomical relationship can be secured with them. Up to the present time we have never had porcelain teeth fulfilling either of these requirements, and dental prosthesis, therefore, has never had a creditable esthetic or anatomical basis. . . . I have said that the present status of dental prosthesis is a disgrace to the profession, and that statement, in my judgment, is not one whit too strong. I am doing what I can to remedy the present condition of things . . . and, what is of far greater interest to me, to find out the real attitude of this representative organization of my native country toward the subject. . . .

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[1] Read before the National Dental Association, in general session, at its annual meeting, Denver, Colo., July 19, 1910. Summarized from *The Dental Cosmos*, 1911.

What to Want

"What to want, then, becomes the most important problem in life. Our wants all center about the hope of realizing an ideal of some sort, and the great mistake that nations, organizations and individuals are constantly making is in accepting something less than their ideal. That constitutes the fall of man; it is for that compromise that he is always being driven out of Eden. A little sluggishness of the gray matter of his brain, perhaps; a little torpidity of imagination, and he accepts the little prize waiting there at his elbow and forfeits the splendid reward he might have had tomorrow. 'A bird in the hand is worth two in the bush,' says the practical man, and he sells himself for the dollar offered today, just a little too dull to see that he might have had the bird in his hand and the two in the bush and all the forest and all the birds—if only he could take the longer view. That represents the difference between the so-called practical man, who is really the most impractical creature on earth, and the idealist. The practical man not only wishes to have his feet solidly planted on the earth, but he desires also to grip it with his hands. In other words, he simply wants what is within reach, and with that he is content. . . .

⁂

"But the idealist is always a little disturbed by the working of that divine discontent which arises in the imagination and the chief characteristic of which is the power to realize deferred values. He represents the very spirit of evolution —the force that is always in the effort to bring something higher out of that which is lower. He is never satisfied with things as they are. . . . He is the reformer, the minority, the unpopular, but he pushes the world along, and the worst of his lot is that he is shackled to that hulking big brother of his, the practical man, and has to drag him along also.

"This little homily is introduced near the beginning of my lecture for the purpose of forcing you all to consider yourselves idealists. I want you all on my side, 'on the side of the angels,' as dear old Dr. Atkinson used to say, and after these opening remarks I imagine there is not one of you who will dare even to think of himself as a so-called practical man who has the 'prudent conservatism of the animals and is satisfied with things as they are.' I shall assume, therefore, that I am speaking to an audience of idealists, and that our ideal in this matter is the highest possible standard for dental prosthesis.

Can Dental Prosthesis Become Genuine Art Work?

"Now, the first question I wish to ask is a vital one, which goes straight to the heart of the whole matter. The answer to that question determines, from my point of view, the whole status of this branch of our professional work. And that question is: can dental prosthesis be raised to a position where it can properly be regarded as art work? If it cannot, then I see but little hope of lifting it out of the slough of mere mechanical drudgery where it now lies. But if, as I think, it is capable of taking rank as genuine art work, if the public can be educated to recognize it as such, and if, as I think, it offers a far wider scope for the exercise of artistic knowledge, judgment and skill than any other branch of our profession and than many other things which are accepted as art work, then there is a hopeful, encouraging outlook for this long-neglected branch of our profession.

"Now, if we are going to consider this question quite seriously . . . we must first determine what art work really is, because obviously we cannot discuss the esthetic or artistic basis of dental prosthesis unless there is an artistic basis to discuss. What is art? There are many definitions of art in print, and I can only allude to some of the more important of them.

Definitions of Art

"Tolstoy has devoted an entire volume to a discussion of the question, 'What is art?' . . . According to him, infectiousness is one of the primary conditions of all good art. The artist must infect all who look at his work with something of the feeling which prompted him to do it. . . .

"I think another modern writer has made an important contribution toward that discovery. He has produced a book in which he discusses the theme, *Delight the Soul of Art.* That, also, comes close to the heart of the matter. The artist must surely have delight in his work, and that in itself should constitute the larger part of the impulse and feeling which moves him and which he wishes to communicate to others. Delight or joy, as a moving force, lies very close to the heart of the creative impulse. . . .

"You may regard one serious part of my effort today as an attempt to bring such new motives to bear on our work as will enable us to find great delight in doing it and real joy in its accomplishment, and I will give you this as a good working definition of art: *art is the creative instinct in man, born of imagination and expressing itself with joy.* Any product of human knowledge and skill which contains evidence of *imagination and delight* on the part of its creator is a work of art.

True Art Implies an Intimate Study of Nature by the Artist

"And I should hasten to add to that the statement that the characteristics of all good art throughout all time have been founded on or have been due to a most patient, prolonged, intimate study of nature on the part of the artist, and his power to select from this study whatever is truly significant and vital to his theme and to reject all else. The degradation of any art has always come about by the introduction of certain conventions or fashions of treatment, which men copy from each other. The artist no longer goes direct to nature for his inspiration, or attempts to express directly the emotion which nature produces in him, but he tries to express something prescribed for him by conventional forms and rules. He no longer makes an effort to express *himself* with joy, but tries to express at second hand the joy of some one he calls a master. . . . Art work of this sort becomes more and more exact, mechanical, and lifeless, or, in other words, conventional. . . .

"Well, now, I think we may sum up our answer to the question, 'What is a work of art?', by saying that it is a human rendering of any beautiful object in nature. Profound knowledge of the object rendered, together with imagination and delight in the craft, must be evident in the finished work. I am, of course, perfectly aware that there is a special definition of art which is more particularly applied to excellence of craftsmanship, and I know that this definition specially applies to our work, but in this paper I wish to call attention to and to emphasize the importance of that attitude of mind toward our work which recognizes the higher aspect and interpretation of art. All art, in its broadest significance, is an interpretation of life.

* * *

"My next object will be to show you how far the artificial teeth of today fall below the standard we have set up, and then to examine the possibility of our being able to reach that standard, that ideal, as applied to dental prosthesis.

"Long familiarity with the mechanical perfection and hard, exact, geometrical outlines of artificial teeth has undoubtedly blunted our sensibility and perception of the far finer beauty of the natural teeth. . . .

"I will show you one more set of natural teeth in contrast with artificial, and this example is particularly interesting from the fact that I sent the incisors of the natural set to three of the largest firms engaged in manufacturing and selling artificial teeth, with a request for a set matching the natural teeth as closely as possible. The photograph on the screen shows the best that they could do. (Figure 76.[1])

"The mere exhibition of these forms is an unanswerable argument against the present condition of things. Of the faults of our present artificial teeth, from the standpoint of utility, I shall speak later. I am now concerned only with their esthetic aspect. If the practitioner in dental prosthesis is to produce a work of art, his raw material must give opportunity for the display of his artistic knowledge, taste and imagination. He must be able to take delight in his work. Now, that is hardly possible with such material as he can command today. In truth, the more competent the man is, the more impossible it becomes for him to find delight in his work. For years I have not taken up an artificial set of teeth in the preparation of a denture without a feeling of exasperation at the patience or indifference or ignorance of the dental profession in using such mechanically perfect travesties of human teeth.

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[1] *The Dental Cosmos*, 1911, page 7.

"The first step toward remedying this deplorable condition of things is to get porcelain teeth of the highest possible standard of artistic merit. The natural teeth are among the most beautiful objects in nature. There is nothing more subtle in nature, from the artist's point of view, than the curves of a human tooth. I believe there is no more difficult thing in nature to model than a human tooth. If we are to be artists in our work, we must understand and appreciate this. If we are to produce works of art, we must closely study this subtle beauty of the natural teeth and reproduce it in dental prosthesis. A set of artificial teeth should be such a perfect imitation of nature that even the most perfectly trained eye should be unable to discover whether they are natural or artificial. (Figure 77.[1])

* * *

"A long and critical study of the natural teeth has shown that there are but few typical or characteristic forms, and of these few forms there is an indefinite number of very *slight* modifications. The fact that there is not so great a variation in teeth as in faces, or in the other features of faces, is in accordance with the law that the lower the form of organization of a tissue the less liable it is to change and variation; or, perhaps I should say, the slower is change effected. The difference between the highest and lowest type of brain in any civilized race is very great. The teeth from the skulls containing such brains might be indistinguishable. . . .

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[1] *The Dental Cosmos*, 1911, page 9.

"I have also discovered—at least it is a discovery as far as I am aware—that the shape of the maxillary arch has for its special correlation not the length and width of the skull as a whole—although it is, of course, to some extent correlated with the skull—but the zygomatic arches. . . . And, furthermore, the direction of the curve formed by the buccal surfaces of the teeth follows almost exactly, in the great majority of cases, the curve of the zygomatic arches.

"I shall show you photographs of skulls from a great range of races as wide apart as the Patagonians and Fuegians are from the modern European, and also a few very ancient skulls, illustrating this point. (Figs. 80-83.[1]) If you think for a moment, is not this correlation exactly what you would expect when you consider the attachments and actions of the great muscles of mastication, more especially the working of the temporal and masseter muscles? . . .

* * *

"In the very notable series of articles which Professor Gysi of Zurich has contributed to *The Cosmos,* he has shown the anatomical and mechanical bases of dental prosthesis to be so intimately associated as to be impossible of separation. His paper is such a thoroughly scientific and exhaustive presentation of this phase of my theme that it hardly seems necessary for me to dwell at any considerable length on details. . . .

"A few earnest workers in the profession have been trying to get a natural, anatomical articulation of artificial teeth which are made from models that have never been set up and articulated in any scientific manner. And that is another astounding fact. We, as a profession, like to think that we

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[1] *The Dental Cosmos,* 1911, page 17.

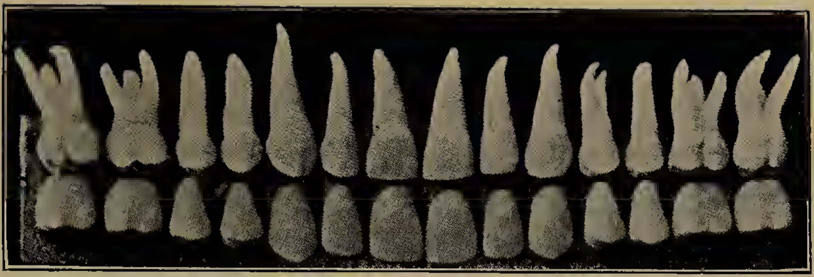

FIG. 76

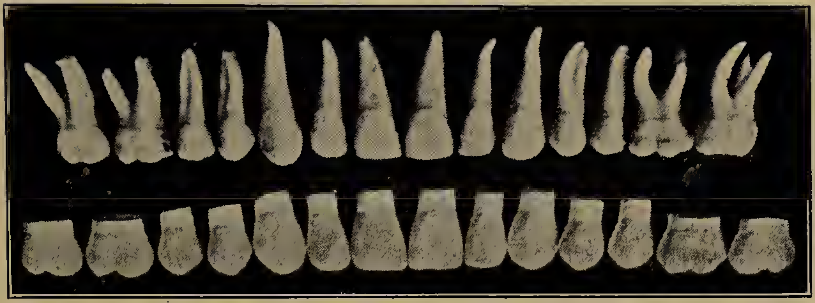

FIG. 77
Upper set of natural teeth and set of plaster models from them, carved one-fifth larger to allow for shrinkage in porcelain in baking.

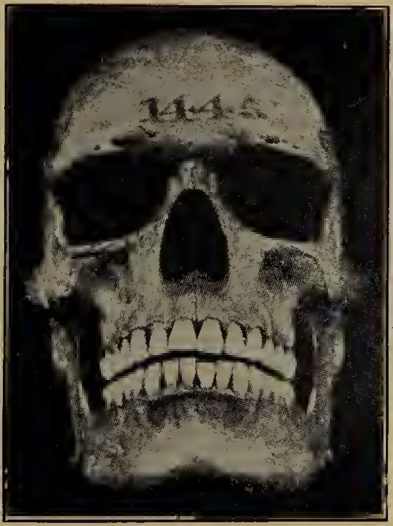

FIG. 78[1]

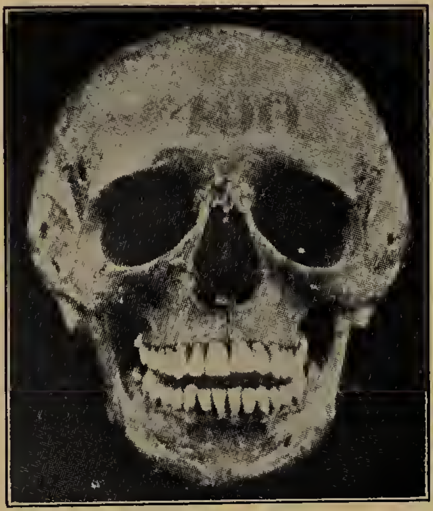

FIG. 79[1]

Illustrating the fact that nature often presents striking disharmonies. Here are two skulls which present about as wide a divergence in shape as can be found, but the teeth in both are of nearly the same size and shape. If there is harmony in one case, there must be striking disharmony in the other.

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[1] *The Dental Cosmos*, 1911, page 18.

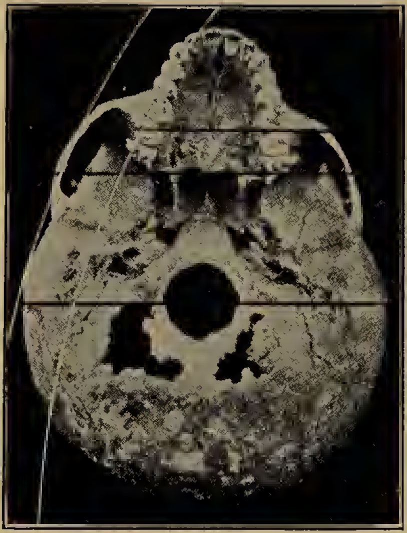

FIG. 80

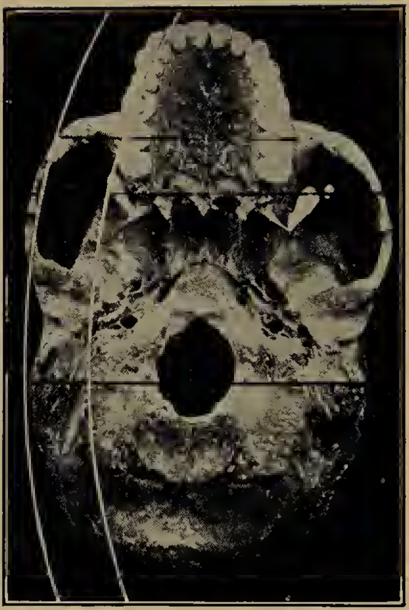

FIG. 81

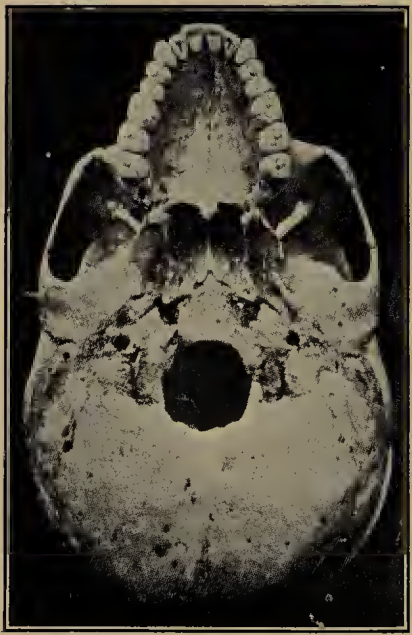

FIG. 82

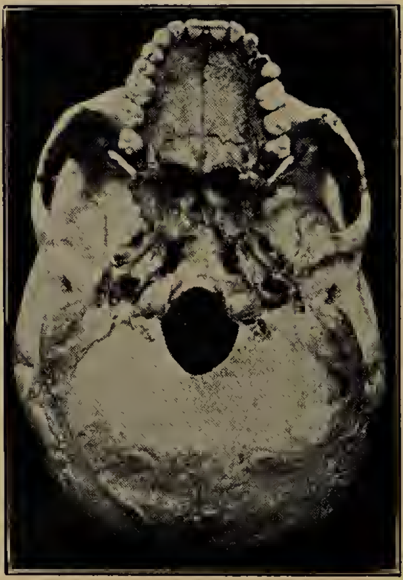

FIG. 83

have artistic proclivities and accomplishments in our work. We also like to think that we are cultivating a scientific attitude of mind toward all professional questions. But I am going to say to you that in this field of prosthetic dentistry we, as a profession, stand without sufficient rags of accomplishment to cover our scientific and artistic nakedness. In the making of that which constitutes the foundation of dental prosthesis, the porcelain teeth, hardly a single scientific principle has been brought to bear on the work with reference to their efficiency in the mouth. And as to that other equally important aspect—well, they may, perhaps, be considered *cosmetic,* may properly be ranked with puffs, powders and perfumery, but esthetic, artistic, they certainly are not.

"Let us rise up now and join hands and do away with this condition of things. Let us have the raw material for scientific and artistic work. Let us have something that will be a credit to the profession, and then we can demand from the public that recognition for our work that is due to all valuable scientific and artistic productions."

Discussion

Dr. E. S. Gaylord, New Haven, Conn. "I shall not tax you with a long discussion of this paper, but I take pleasure in addressing you on account of my relations with the essayist in his great work. We should congratulate ourselves upon the fact that this work is being performed by an American, and that he is willing to devote his time and his money to come such a distance to present this subject to us. . . .

"We must inquire of what value this great improvement would be to each of us. If we recognize it as being of value, I am sure we cannot do otherwise than demand of the manufacturer a certain number of sets of these teeth. If you are willing to put your hand in your pocket to pay for these perfected goods, it would greatly expedite what Dr. Williams so much desires, and this end would be much more quickly attained than by merely talking over the matter or writing letters indorsing the plan proposed and letting the manufacturers use their own judgment as to whether there is a demand for such improved goods after they are produced."

* * *

Dr. Geo. H. Wilson, Cleveland, Ohio. "It has been a great treat to us to look at these specimens which we have had portrayed today. It is a blessing that we have such a man as Dr. Williams in our profession, and that he is willing to devote his time and money to perfecting this essential feature of our profession. It will never be possible for the operative dentist to preserve the natural teeth for all time, although we so much desire to keep them intact. We hope that the present methods of operative dentistry will be so improved that the life of the natural denture will be much prolonged. However, there will always be a demand for artificial dentures, and if we are to maintain our claim of being artists and esthetists, we must endeavor to make our art conceal art, but under present conditions that has been quite a difficult task.

"It is true that we have been obliged to accept what was placed before us, but we have not been willing to give the time and labor to prepare the material provided in as artistic a manner as possible. On account of the money-getting craze of the age, we have not been willing to do the best work we could, therefore it is well to have material placed upon the market that will save much of this labor. The essayist has certainly presented a plan that will minimize labor and give us a far superior product.

"Another feature to which the essayist called attention is the relationship between the dental and zygomatic arches. That is simply a modification, reduced to a practical method, of the temperamental basis by which we have been working. The study of temperament is a very difficult one as laid down in the textbooks. It is so complicated that it forms no certain guide to work upon, but when we can reduce it to a few simple rules, as suggested in this paper, it will be an easy matter for us to follow nature and secure a type of teeth that will harmonize. Harmony is the thought expressed in one word; it is the foundation of esthetics as applied to our work."

* * *

Dr. N. S. Hoff, Ann Arbor, Mich. "There is much that I should like to say in the discussion of this paper, as it treats a theme which in my view requires very careful consideration and very earnest discussion, but our time is so limited that it will not be possible to do more than take a mere glance at the subject presented to us.

"I would characterize this paper as one of the most important contributions to our literature. It has illuminated the field of our practical work. I am sure it will come to be recognized as one of the great classics on a subject that we are not accustomed to consider from such a standpoint.

"I feel under the deepest obligations personally, and I know you all do, to Dr. Williams. That a man of such able and eminent qualifications has undertaken a work of this kind and has investigated the subject with so much thoroughness and from so scientific and artistic a standpoint puts it on the highest possible basis and challenges us to assist him in his most worthy ambition to lift this work to a professional standard.

"The essayist has brought out so many of the artistic phases that this feature of the address is to me of even more value than the practical aspect, or the providing of suitable materials for our work. There has never been so full and comprehensive a presentation of this subject from the artistic side in all our literature, to my knowledge.

"This work is so tremendously important and so comprehensive that I want to offer a resolution which I have written on the spur of the moment, and which, though it is inadequate, may in some slight degree at least represent to Dr. Williams our attitude toward him and his great work, and I trust it will inspire the manufacturers of artificial teeth with a greater degree of confidence. I offer this resolution and move its adoption:

Resolved, That the National Dental Association, in convention assembled, cordially indorses the work done by Dr. J. Leon Williams in undertaking to improve the anatomical forms of artificial teeth. We believe that his labors have produced better types and forms of teeth than we now have, and we respectfully request that our manufacturers take steps to provide these teeth for us at as early a date as possible."

* * *

The motion was regularly seconded and carried unanimously.

Dr. Gaylord. "In view of the great value of Dr. Williams's work to ourselves and to humanity, I move that we present to him a vote of thanks for coming before us and presenting this subject in such an able manner."

Dr. Wilson seconded the motion and it was carried unanimously.

CHAPTER XVIII

DR. WILLIAMS DISCOVERS TYPAL FORMS IN NATURAL TEETH

DESPITE the great heat of midsummer in New York and its exhausting effect on Dr. Williams, who, in England or on the Continent, had been unaccustomed to it for many years, he plunged into work immediately after the meeting of the National Dental Association. The months of August and September were spent in conferences with members of the profession and in such museums as afforded collections of crania.

RESOLUTIONS OF APPROVAL

In October and November he appeared before the American Academy of Dental Surgery of New Jersey, the Metropolitan District of the Massachusetts Dental Society and the Institute of Dental Pedagogics. The following resolutions were passed:

WHEREAS: The American Academy of Dental Surgery recognizes the great value to the profession of the work which Dr. J. Leon Williams has undertaken of making improvements in the artistic and anatomical features of artificial teeth,

THEREFORE RESOLVED: That the American Academy of Dental Surgery pledges its loyal support to Dr. Williams in his efforts and requests the manufacturers with whom he may arrange for the production of these teeth to proceed with the work under Dr. Williams's directions as rapidly as is consistent with the highest standard of perfection.

—— —— —— —— ——

RESOLVED: That the Metropolitan District of the Massachusetts Dental Society enthusiastically endorses the new system of teeth shown to the Society by Dr. J. Leon Williams and joins in the demand that the manufacturers of porcelain teeth place the teeth, according to his system, on sale to the profession at the earliest practicable date.

—— —— —— —— ——

The Institute of Dental Pedagogics assembled at Toronto, Canada, at their Seventeenth Annual Meeting, have listened to an address by Dr. J. Leon Williams on the subject of Improvements in Artificial Teeth and have examined the models submitted by Dr. Williams to illustrate his views on improvements in form and articulation of artificial teeth, and they desire to express their hearty approval of this work and their opinion that it constitutes a marked advance on anything heretofore accomplished in this field.

And the Institute of Dental Pedagogics respectfully asks that any manufacturers of artificial teeth with whom Dr. Williams may make arrangements for the production of his teeth will render all assistance at their command to produce the most perfect results attainable and will also make all reasonable efforts to supply the profession with a good variety of these new teeth, in the ordinary form and also in the new models specially designed for bridgework, at the earliest possible moment.

* * *

These endorsements, with others which were received through different channels, were accepted by the Company as sufficient evidence that the profession at large was interested in further improvements in the forms of teeth, and the preliminary studies in tooth forms and dimensions which Dr. Williams had begun in London were continued.

The Scope of the Work Broadens

The conferences with Professor Gysi and the prospects that there would be devoted to the formation of the occlusal surfaces of the bicuspids and molars a much greater knowledge of the requirements for efficient mastication than had ever before been applied to the shaping of posterior teeth considerably broadened the scope of the whole project. At almost every turn some form of new knowledge was required for which careful search had to be made, and it soon became evident that it would be impossible for Dr. Williams to give personal attention to each of the many phases which the undertaking was developing and that it was imperative for him to have one or more associates who could assume charge of certain portions of the work.

The author's training had fitted him to be especially helpful at this time, and in the summer of 1910 he became definitely associated with Dr. Williams as coworker. He had graduated ten years before from the University of Michigan, had practiced for six years in a country town where artificial dentures not only must be made but must be made satisfactory to patients, had instituted and conducted the Research Division established by The Dentists' Supply Company in 1906, had devised the methods of ordering artificial teeth by millimeter measurements (although it appears that several workers had independently devised very similar systems), had been responsible for the production of the anatomical moulds in Twentieth Century bicuspids and molars, had correlated the elements of a system of anatomically articulating teeth and had devised and conducted the lectures and clinics by which that system and the improved forms were presented to many dentists. He had also served on the advisory board which had recommended that the Company undertake the production of the new system of teeth proposed by Dr. Williams.

BAFFLED BY UNSCIENTIFIC PRINCIPLES

Dr. Williams was unable to obtain from other members of the dental profession the assistance he required in deciding on the forms and sizes of anterior teeth which would prove most suitable. It was impossible for anyone then to understand why the search for this information proved so extremely baffling, but it is now known that the principles on which the studies were being conducted were scientifically incorrect and that there could be no satisfactory solution until right underlying principles had been found.

Dr. Williams, like everyone else in the profession, was a believer in the Temperamental Theory. He accepted the four basic temperaments and their characteristic forms of teeth and planned to build his system by one crossing of each temperamental form with one other form, giving ten forms. Each form was to be in six sizes.

SUMMARY OF THE TEMPERAMENTAL THEORY

The term "Temperamental Theory" is now so rarely heard in the dental profession that the next generation of dentists will have no conception of the sway it exercised over the brightest minds in the profession until it met its

Waterloo at the hands of Dr. Williams in 1914 or of the endless confusion which resulted from the efforts to follow its supposed principles. It will be interesting to record its outline here.

The Temperamental Theory, probably originated by Hippocrates in the fifth century B. C., may have been in the first place a rather simple theory of classifying the ailments from which people suffered and the macroscopic symptoms. It may have later become a system for classifying people as to their susceptibility and immunity to various disorders. In the years that followed, especially in the eighteenth century, its adherents developed it to a degree of which its originator probably never dreamed. The theory divided the organs of the body into four groups—nerves, muscles, glands and blood—and assigned to each group a distinctive influence of compelling power in body formation and in physical and mental functions. This influence was given the name "temperament."

Since no person was composed solely of nerves, solely of muscles, solely of blood or glands, there were no pure temperaments. Each person presented something of all four temperaments, but one set of organs—and, consequently, one temperament—was believed to be dominant in each person, modified by the other temperaments according to the proportions in which they were present. The dominant temperament was supposed to decide, inflexibly, the bodily stature, the form of the nose, the color of the eyes, hair, skin and teeth, the nature of the occupation by which he should earn a living, the sports in which he should find recreation, and the kind of woman he should marry. Some devotees governed the nature of religious belief by the temperament, assigning a strong belief in Hell to those persons in whom the liver, as the largest of the glands, was dominant and a belief in Heaven to those in whom the blood dominated and who were therefore more sanguine as to the future. According to them it was necessary only to decide on a man's temperamental groove and fit him into it to insure his happiness here and hereafter.

The Temperamental Theory in Denture Prosthesis

The application of this theory to the making of artificial dentures stated that the form, size, color and arrangement of teeth suitable for each person were inflexibly determined by the temperament. The dentist need not select the tooth form. He need only decide whether a patient had more muscle than brain or more liver than brain and muscle combined. The decision settled the form, size and color of the teeth and the manner in which they should be arranged on the denture. And some textbooks published imposing tables of characteristics governing such selection.

The theory was the logical descendant of a series of brainstorms by people who could write but who had never looked to see if what they wrote was true. The most devoted adherents of the theory differed radically as to temperamental characteristics or wrote in terms so general as to have no practical value. The theory had, at this date (1910), been completely discarded in every branch of medicine and was not wholly believed in dentistry, but it persisted for want of something better and led to endless confusion and difficulty. As Dr. Williams was to write about it later, "In all the wearisome, contradictory and irrevelant details . . . there is never a hint of a fundamental principle on which a student could take his stand for the exercise of his taste and judgment." But he and his coworkers did not know this at the time and they struggled valiantly in the maze of indeterminate indecision. Baffled in America, Dr. Williams returned to London in October 1910 to avail himself of the excellent collections of crania there. The author joined him there in 1911 and they worked diligently together, but always with the sense that something unseen was holding them back from the key knowledge they sought.

The Physical Strain on Dr. Williams

In reading the story of the nearly seven years of continuous effort by Dr. Williams to secure better teeth, from the first letter in the *Items* in 1907 to the introduction of the teeth in 1914, it should be remembered that it was necessary for him to respond to the demands of his London practice, which he had made exacting by the high quality of service he had long rendered. When not absent from that city, he spent most of each day at the chair. The studies, drawing, correspondence and carving were done in what remained of the day or in the evening and night. It was not uncommon for his working day to comprise from fourteen to sixteen hours. As Dr. Williams was then nearly sixty years old, it is not surprising that the labors which he had undertaken in America, the frequent long journeys and the zeal and continuity with which he had worked after his return to London affected his health, so that in September 1911 he was compelled to go to his favorite haven of rest, the Swiss Alps. He improved this occasion by having another long conference with Professor Gysi and returned to London, a few weeks later, rejuvenated and filled with new enthusiasm.

THE DISCOVERY OF TYPAL FORMS

And then, late in November 1911, he made the discovery which was to mark an important epoch in denture work—that there are no temperamental or racial forms of teeth, but that there are three typal forms, common to all races and time of which we have knowledge; that all other forms result from combinations of the elements of these three; and that, when he had mastered the elements of these forms and the laws by which nature combines them, he could produce a series of forms that would be harmonious with nature's best work and meet the requirements of practice as no other forms could.

The discovery came about in this way. Dr. H. E. Friesell had sent Dr. Williams nearly a bushel of extracted teeth.[1] Near the close of a period of study, somewhat fatigued and perhaps a little off guard, he sat studying the centrals, one after another, seeking the key to the principle of outline form which had so long baffled him. When he had examined a large number and was about to stop, he discovered that, when putting the teeth down, he had unconsciously sorted

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[1] Dr. Friesell afterward sent to Dr. Williams twenty sets of very fine natural maxillary incisors. All of these teeth were of the greatest assistance to Dr. Williams, and to Dr. Friesell and those who helped him procure these teeth he has always felt an abiding sense of gratitude.

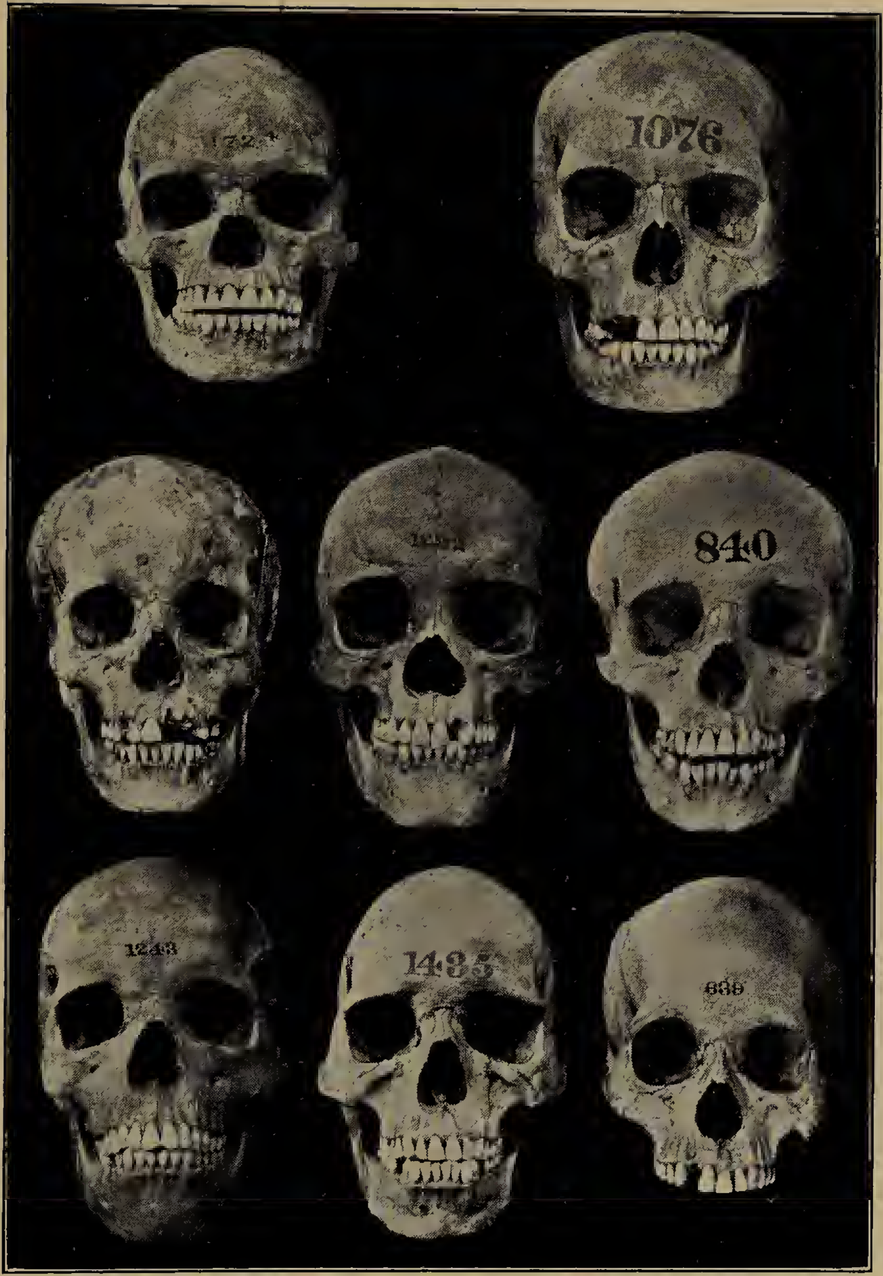

FIG. 85
Eight skulls of unlike size and form, all with teeth of ovoid type. The form and size of the teeth bear no relation to the form or size of the skull.
Nationalities from left to right are: Australian, Sandwich Islander, Ancient Egyptian, Kaffir, Chinese, African Savage, New Hebridean, Hindoo.

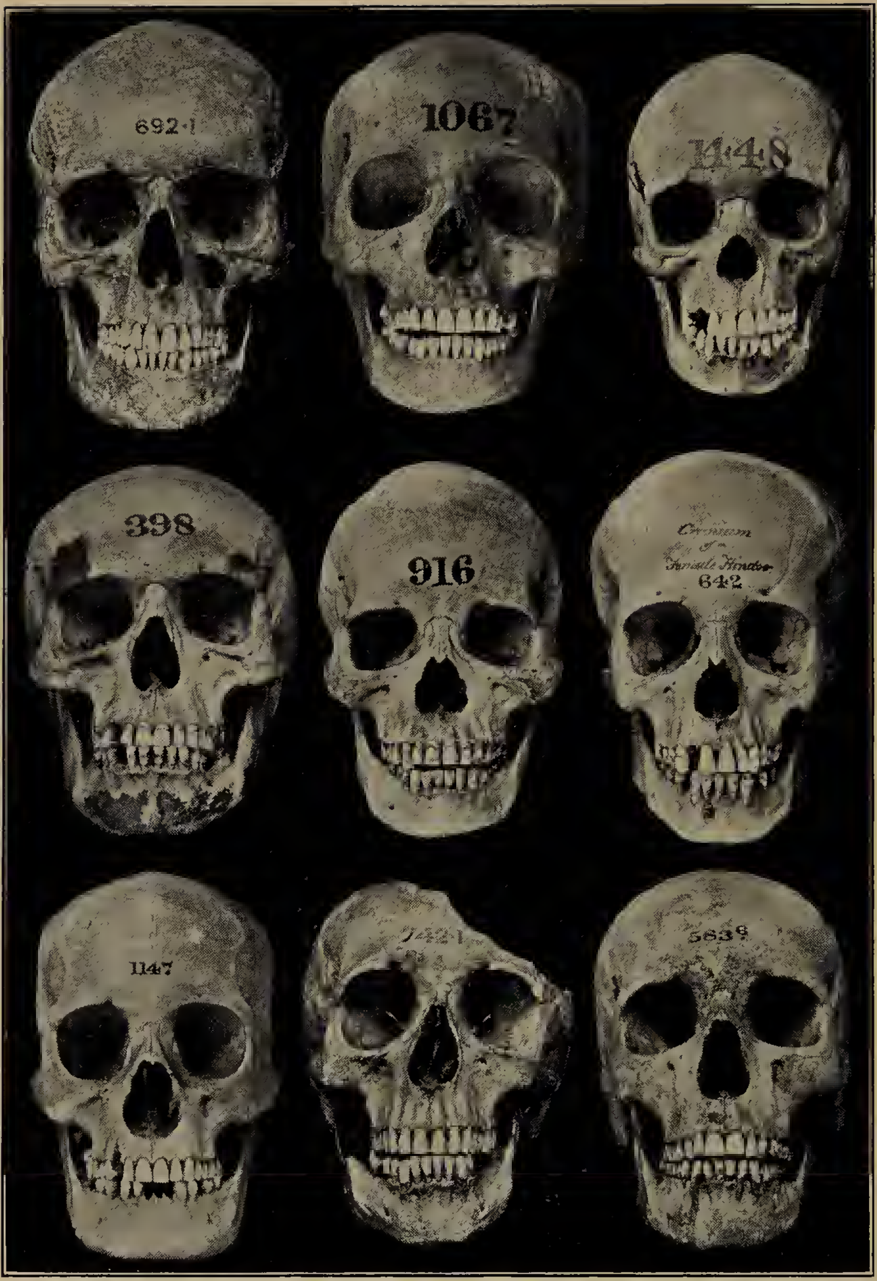

FIG. 84

Nine skulls of different races and unlike size and contour, all with teeth of square type. The form and size of the teeth bear no relation to the form or size of the skull.

Nationalities from left to right are: Spanish, Sandwich Islander, New Hebridean, German, Javanese, Hindoo, Fiji Islander, Italian, Ancient Egyptian.

them into four groups. Pondering what this might mean, he studied the teeth in each group. He saw that the teeth in the first were very much alike in outline form; that the teeth in the second were like each other but unlike those in the first; that the teeth in the third were like each other but unlike those in the first and second groups; and that the teeth in the fourth were less like each other than those in any of the other groups. He could make nothing of it, so he left the teeth as he had sorted them and went to bed.

* * *

During the hours of sleep that night his mind must have worked on the problem because, when he waked the next morning and lay pondering what the groups of teeth might mean, there came immediately the realization that the teeth in each group must have come from people of different races and, therefore, of different temperaments. Like a flash it dawned upon him that if this were true, there were no racial or typal forms of teeth, but certain fundamental forms common to different races and temperaments. Dressing hurriedly, he studied the teeth again. And now the significance of the fourth group was plain. The teeth in that were composite forms, made up of elements of the forms in the other groups. The most painstaking search did not reveal a single composite form which was not visibly related to one of the other three simpler forms. He was at the museum by the time it opened. And there, in every racial collection of crania showing a dozen sets of maxillary incisors, he found the three typal forms, one square, one tapering, one ovoid, and one or more composite forms. Not satisfied, he studied the collections of crania from the manlike apes and there found the same typal forms in stronger character. Gone was the Temperamental Theory with its supposed relationships to tooth form and size! Passed forever its obscurities and absurdities! Settled thenceforward, for all time, the foundation for a system of tooth forms that would meet the requirements of prosthetic workers as no other system had or could! (Figures 84, 85.)

DRAWING AS A METHOD OF TRAINING

Dr. Williams immediately changed his plan of study. Some of what he had done during the last four years fell naturally into place under the new discovery. He unhesitatingly abandoned whatever did not fit and started anew. He determined to master the elements of each typal form, not only the easily discernible elements but the subtler touches

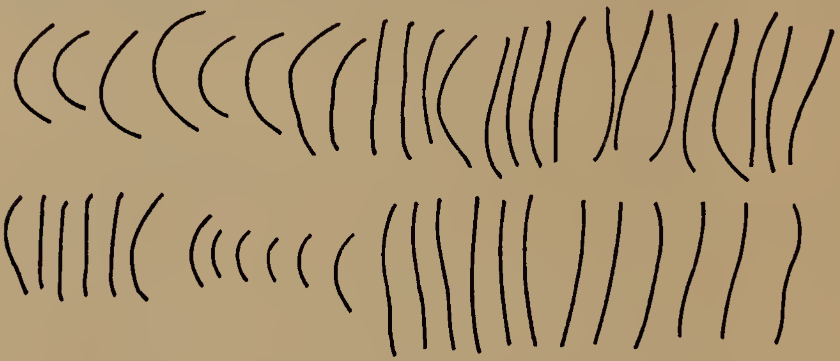

FIG. 86
Elements of design, separated.

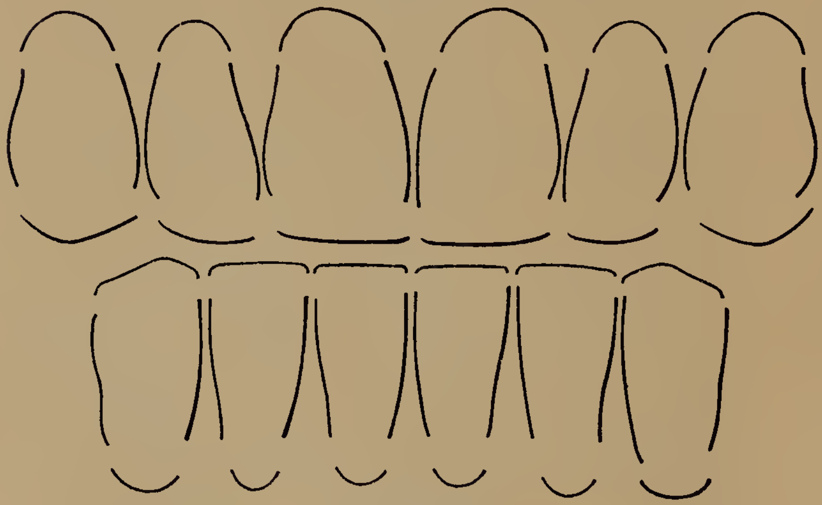

FIG. 87
Elements of design, partly assembled.

which, perhaps hardly visible in themselves and rarely perceived, impart beauty and distinction to a fine tooth. He wanted to learn also the law which he felt sure that nature must follow in combining elements to make the composite forms. His artistic training, of which more will be said elsewhere, was of great value, as was the experience he had gained in learning to carve teeth. He put aside his carving tools, got out his drawing materials and for four weeks devoted every spare moment to drawing typal forms and their elements, until the walls of his large studio were covered with drawings. He got either the law or the sense of combination. Then he was ready to carve. (Figures 86, 87.)

The Problems of Form Classification

It is easy now to classify practically all forms of natural teeth, but when Dr. Williams first did it, there were only the beginnings of knowledge as to what constituted a sound basis for classification. In the large collection of extracted teeth sent to Dr. Williams there were many maxillary centrals which were easily recognizable as typal forms, but by far the greater number of teeth were not of typal forms. They presented an apparently endless number of apparently lawless combinations of the elements of the typal forms. The differences among them were sometimes slight, sometimes great, but critical study showed that in each tooth one type was always at least a little more prominent than the other two; that is, none of the forms appeared to be equal mixtures of all three types.

The problem presented several aspects:

To classify all the teeth as to type.

To classify all the teeth in each type into typal forms and modifications of the typal forms.

To decide which of the modifications were most frequently seen in natural teeth and would therefore be most serviceable in artificial teeth.

To eliminate from the typal and modified forms the elements which were not pleasing or not suitable for artificial teeth and to combine the pleasing elements into forms suitable for denture work, representative of frequently seen forms in natural teeth and capable of modification by dentists to meet individual requirements.

Selecting Representative Tapering Forms

The story of how Dr. Williams solved these problems in the tapering type will illustrate the method employed for the other types also. He laid out in a horizontal line a large number of tapering natural teeth, placing all of those of the typal form on the left and progressing toward the right as the degree of modification away from the typal form increased, until on the extreme right were placed those in which the dominance of the tapering type could barely be distinguished.

DISTINGUISHING CHARACTERISTICS OF TYPAL TAPERING CENTRALS

Before he began the carving of any of the typal forms during the weeks when he was drawing the elements and combinations, he had asked himself the question: "What are the distinguishing characteristics of the central of the typal tapering form?" He had answered it, in his drawings, as follows: "A more rapid convergence upward of the approximal sides than in the square or ovoid type; a straight or slightly curved mesial surface; a delicate double curve involving the middle and incisal thirds of the distal surface, on which the beauty of the tooth in no small degree depends; and a relatively flat labial surface in the incisal and middle thirds." He had answered also the question: "What adaptation of this form is most desirable in plate work?" "The approximal sides should not converge too rapidly; they should not be too straight, and the labial surfaces should not be too flat." That meant that the form for prosthetic work should exhibit a wide or medium-wide neck, that the mesial surface should be slightly curved, that the distal surface should exhibit the characteristic double curve and that the labial surface should be slightly rounding, but not so rounding as in the other types.

THE COMBINATION OF FORM ELEMENTS

When Dr. Williams isolated the teeth of typal tapering form from the rest of the row and studied them separately, it was immediately apparent that among all the teeth of typal form not one combined all the desirable characteristics and avoided all the undesirable. This can be seen by studying the photographs of ten typal tapering centrals (Figure 88). In some the necks are too narrow; in some the approx-

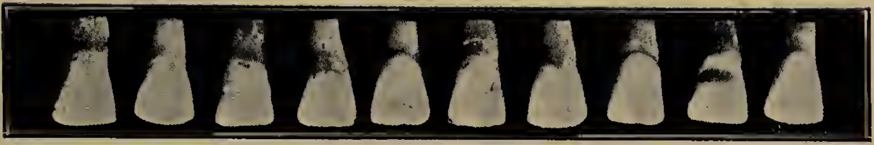

FIG. 88

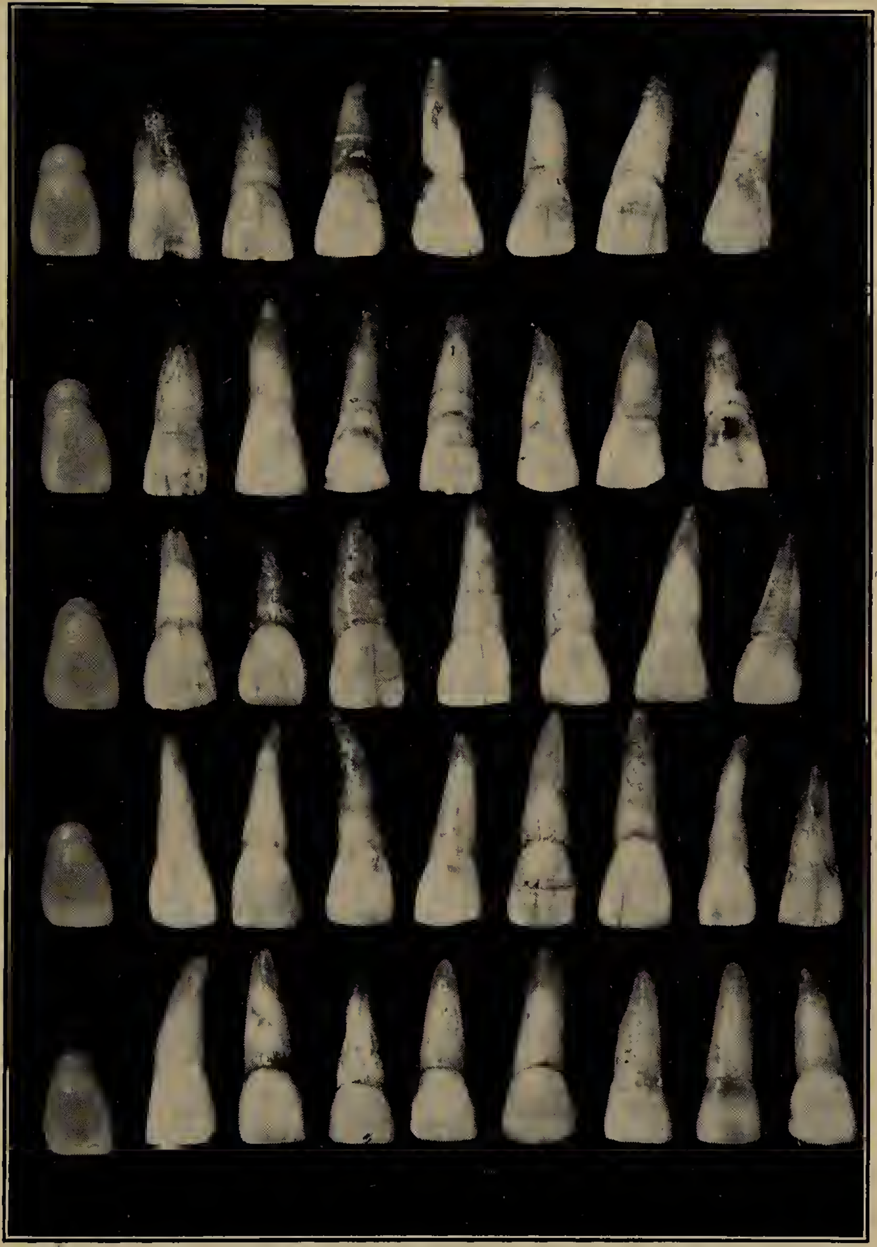

FIG. 90[1]

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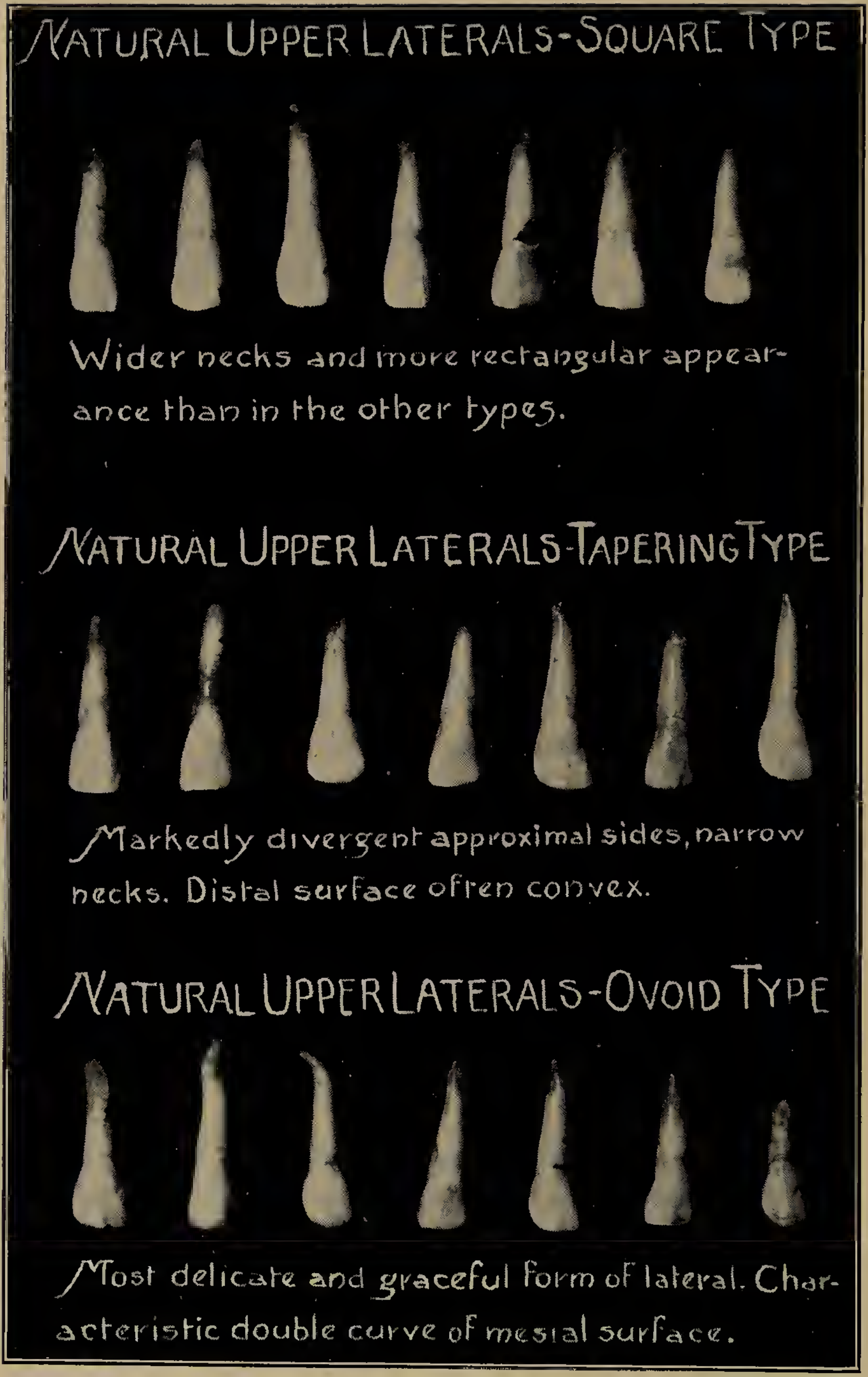
[1] Exigencies of inserting the illustrations on this page necessitated placing Fig. 90 out of regular order.



NATURAL UPPER LATERALS-SQUARE TYPE

Wider necks and more rectangular appearance than in the other types.

NATURAL UPPER LATERALS-TAPERING TYPE

Markedly divergent approximal sides, narrow necks. Distal surface often convex.

NATURAL UPPER LATERALS-OVOID TYPE

Most delicate and graceful form of lateral. Characteristic double curve of mesial surface.

FIG. 91[1]

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[1] Exigencies of inserting this illustration necessitated placing it out of regular order.

imal sides are too straight; and in some the labial surfaces are actually hollow in the incisal thirds. Perhaps the variation in outline can be better seen in the very accurate outline drawings of eight other typal tapering centrals shown in Figure 89.

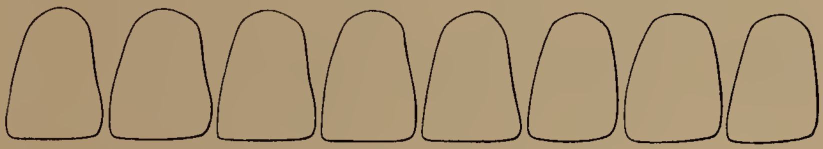

FIG. 89

What he had to do then was not to copy any tooth which he had found, but to apply the principles exhibited by all the teeth of that type to the production of a single form which should represent the best in all such teeth. Thanks to his artistic training and the weeks which he had spent in drawing, Dr. Williams was able to eliminate the unpleasing and unsuitable elements and to combine the pleasing elements into a form which he believed to be representative of the best in all that he had studied, suitable for use in prosthetic work and capable of pleasing modification for individual cases.[1]

INTERRUPTING THE PROGRESS OF FORM MODIFICATION

The extracted teeth of typal form which had been placed at the left of the line of tapering teeth were now removed and replaced by the representative typal form which he had carved. Dr. Williams then sought to interrupt the progress of modification, as he moved along the line toward the right, at points which would yield representative forms like those most frequently seen in natural teeth and suitable for use in denture work. About each of these points were grouped a number of teeth which differed among themselves as the typal forms in Figure 89 differ, but which had so much in common that they were clearly related to one another. The plan followed was identical with that applied to the typal forms; that is, the unpleasing elements were eliminated and the pleasing elements combined into a form representative of the best in all and suitable for prosthetic work. An idea of the variations exhibited by individual teeth in the different groups and of the representative forms which Dr. Williams carved can be had by a study of Figure 90.

---

[1] As the result of several years of further study, Dr. Williams has added to his knowledge of the typal forms and their combinations.

This plan, when applied to all types, gave five forms in the square type, four in the tapering type and four in the ovoid type. This number was afterward increased to six in the square type and six in the tapering type.

The Importance of Lateral Forms

While Dr. Williams's achievements in the production of characteristic forms in maxillary centrals have received the greater part of the attention given to the subject by students, it was not more difficult and perhaps hardly less important than the production of characteristic forms in the laterals and, to a less degree, in the cuspids. The appearance of a set of teeth depends, in much greater degree than is easily appreciated, on the forms of the laterals and their harmony between the quite unlike but closely related central and cuspid forms.

The maxillary laterals may be subject to more extensive form variation than are the centrals, but they vary always around a fixed principle. As with the centrals, no single tooth usually presents all the desirable characteristics, but the study of a sufficient number of teeth makes it possible to avoid undesirable characteristics and combine the desirable characteristics into the typal form and the modified forms harmonious with the modified forms of centrals. Illustrations of a few lateral forms will be found in Figure 91 and in Figure 92.

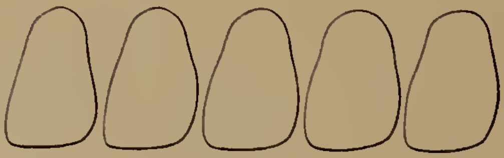

FIG. 92

Dr. Williams regards the maxillary laterals as "form-bridges" between the centrals and the cuspids. He has always felt that not enough attention has been given to their influence on the appearance of dentures. Whereas, in the tapering and ovoid centrals, the distal approximal surface expresses best the character and beauty of the teeth, this expression, in the laterals, is found in the mesial approximal surface. The curvature of this surface in the laterals is strikingly like the curvature of the distal surface in the centrals, but unlike it in subtle ways which charm the student. And, in the ovoid type, there is a relation between the curvature of the mesial surface of the maxillary laterals and the jaw line of the face which cannot escape critical inspection and which cannot but impress one with a sense of an underlying harmony always struggling for expression but not often fully finding it.

So deeply was Dr. Williams enthralled by the possibilities which his discoveries opened to his vision that he nearly discontinued practice, and in the early months of 1913 he carved thirty-six sets of maxillary and mandibular anteriors of the representative forms, in graded sizes, which he believed would be most useful in practice and dispatched them to America to be produced in porcelain. The amount of concentrated effort necessary for such an achievement can be appreciated only by one who has done something similar.

The Significance of Identical Tooth Forms in Apes and Man

Dr. Williams's scientific experience showed him that the existence of identical tooth forms in different races of men and the manlike apes was of more far-reaching significance than merely to enable him to carve proper forms in artificial teeth. He submitted his evidence to a number of prominent anthropologists, including Professor Henry Fairfield Osborn, President of the American Museum of Natural History; Professor Schäfer, President of the British Association of Science for 1912; Professor Keith, Hunterian Lecturer at the Royal College of Surgeons; Dr. Woodward, of the Natural History Museum, South Kensington; Dr. A. Russel Wallace, codiscoverer with Darwin of the principle of natural selection; and Professor Ernest Haeckel, the greatest authority who has ever lived on matters of comparative morphology in man and the lower animals. Many interesting comments were received from these authorities, and no word of criticism adverse to Dr. Williams's conclusions was offered. Perhaps the general reception of the discovery can be made plain by a copy of the letter from Professor Haeckel.

> Jena, 6, 1, 1913.
>
> Dr. Leon Williams,
> London.
>
> Dear Sir.—Your observations on the three different types of the upper central incisors are very interesting, and mainly the fact that the same three characteristic types occur also in the orang-outang and in other anthropoid apes. In my opinion this fact is another new and convincing proof for the near relationship between man and the anthropoid apes, and for the phylogenetic theories that both have been derived from one and the same common ancestor. First, the fact that these three types—in physiological relationship of little value—are so distinctly developed in three morphological directions seems to me an important proof that the way of phylogenetic divergence of characters is the same in man and in the anthropoid apes.
>
> Very respectfully yours,
> (Signed) Ernst Haekel.

Thus a member of the dental profession was enabled to make a contribution to the knowledge of the chain of descent by which man has come from a primitive state to the present.

Dr. Williams Selects a Name for the Teeth

Concurrently with his studies and carving there had been present in Dr. Williams's mind a question as to what name should be given to the new teeth to distinguish them from all others. One day, as he sat working with the articulated teeth and noted how truly and firmly they came together, as no other artificial teeth ever had, and thought of how surely they would increase the stability, comfort and efficiency of artificial dentures, there dawned upon him what seemed a fitting name—*Trubyte*—and by that the teeth have been known in America. Because the significance of that name is incapable of being understood in some of the languages spoken in Europe, the name *Anatoform* was adopted for use there.

CHAPTER XIX

EFFORTS TO IMPROVE THE COLORS IN ARTIFICIAL TEETH

THE determination to make the new teeth of the greatest practical value prompted a desire to improve shades as well as forms. More dentists were dissatisfied with the shades of artificial teeth than with the forms. But this dissatisfaction did not produce suggestions any more constructive than that the teeth should be "more natural." Such literature as could be found did not throw new light on the subject.

STUDIES IN A COLOR LABORATORY

There was in England a certain color laboratory where experts had found a practical method of analyzing a given color into its elements, of measuring the proportions of the component colors and recording them in such way that two colors could be compared and any color which had been measured could be reconstructed. Dr. Williams was far too busily occupied to give attention to this phase of the problem, but he made arrangements for the author to work with the experts of this laboratory in identifying the colors in natural teeth, in analyzing and recording the proportions in which they were present, their distribution in different parts of each tooth and the variations seen in different teeth in the same mouth and in similar teeth in different mouths. The author spent the summer of 1912 in England in this work.

IMPROVEMENTS IN ANTERIOR SHADING

As a result of these studies, a new method of manufacture was adopted for the new teeth by which the colors were placed differently in different teeth, so that the laterals and cuspids were somewhat darker than the centrals. This was an improvement over the method of selecting different shades to make up a set because it avoided the introduction of unlike colors into the anteriors. It was an improvement over the staining and baking method because the color was under the glaze of the surface and therefore permanent. It had the further important advantages of saving time, reducing cost and making it possible for any dentist to approximate the color perspective in fine natural dentures by merely using the teeth as made.

The net result of this work at the time was important in two ways: (1) the teeth, when arranged in the mouth, produced better than had before been possible the perspective on which the pleasing effects of fine natural dentures largely depend; (2) a beginning was made in the recognition and identification of colors and shades in natural teeth, which, years later, was to pave the way for important results.

Reflection of Light from Labial Surfaces

Following the investigation into shades and shading in natural teeth a careful study was made of the manner in which light is reflected from the labial surfaces of natural and artificial maxillary anterior teeth. The labial surfaces of fine natural teeth are rarely smooth. They are usually broken vertically by the developmental grooves and horizontally by fine lines which appear as the enamel might if it had been deposited in tiny waves.

Even when the waves are so small as to be visible only under an enlarging glass, they exert a great effect upon the appearance of the tooth. From different portions of the crest of each wave light is diffused in many directions. There is thus a multitude of tiny high lights among the shadows in all parts of the tooth. Possibly from the greater part of each crest no high light may be reflected directly to the observer, and that part of the tooth will be in greater or less shadow. But the general diffusion prevents concentration of either high light or shadow and produces that effect which is usually spoken of as "soft color."

The labial surfaces of artificial maxillary anteriors, prior to 1914, were generally broken by more or less pronounced vertical developmental grooves and by one or two horizontal markings, more suggestive of defective calcification than of anything else. The remainder of the surface showed the

Dr. Williams and the Author at Work in London.

rounding necessary to form the tooth, but no other markings. As a result, the light was reflected in a mass by whatever area of the tooth happened to be at right angles to the observer, and the light from all the remainder of the surface went elsewhere, so that that portion of the tooth was in shadow. This concentration of light and shadow produced an unnatural effect which might be described by the term "hard" in contrast with the term "soft" used for the natural tooth. The high light was too bright and masked the color of the tooth in one direction, while the shadow was too great in extent or too deep and masked the color in the opposite direction.

"Enamel Markings" to Diffuse Light

As the result of extensive studies, there was placed on the labial surfaces of the new teeth a series of "enamel markings" which diffused the light in much the same way as it is diffused from fine natural teeth. The effect was immediate and important. The concentration of high light and shadow was prevented. Tiny high lights, some of them hardly recognizable individually, were distributed over the tooth, the true enamel and dentine colors were more readily perceptible and the soft appearance of natural teeth was much more closely simulated.

Professor Gysi Carves Occlusal Surfaces

In the fall of 1912 Professor Gysi came to America to finish the carving of the occlusal surfaces of the bicuspids and molars upon which he had done a great deal of preparatory work. Three depths of bite were carved: shallow, medium and deep.

The decision as to which depth of bite to incorporate in the teeth finally turned on the fact that comparatively few dentists were using scientific methods of impression- and bite-taking. If the teeth were to be successful in the hands of dentists generally, it was essential that they be of a depth of bite which would not cause the dentures to be easily dislodged if the impression and bite were not exact. The shallow bite was adopted. By the methods which Dr. Gysi employed this depth of bite could be incorporated in the teeth and yet permit them to exhibit an efficiency heretofore unknown. The elements of the scientific work underlying the formation of the occlusal surfaces have been described elsewhere.[1]

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[1] *Prosthetic Articulation,* Part IV.

CHAPTER XX

THE LAW OF HARMONY BETWEEN FACE FORMS AND TOOTH FORMS

WHEN Dr. Williams discovered the typal forms in teeth, he was already aware that artists recognized three typal forms in faces: square, tapering and round or, as he preferred to call it, ovoid. (Figure 93.) He soon came to see that the resemblance between typal forms in faces and typal forms in teeth was so marked that it might be the result not of chance but of an underlying relationship between face forms and tooth forms. He undertook to find the law of that relationship.

A DEFINITE CLASSIFICATION OF FACE FORMS

His first task was to make a more definite classification of face forms than was then current. When he attempted to do this, he found the same conditions he had found in tooth forms—a few typal forms which differed greatly among themselves and a great number of modified forms which presented apparently lawless combinations of the typal elements.

Finding it impossible to achieve satisfactory results by observing the faces of living people, in 1913 he began to collect photographs of people of distinction in various walks of life. The author made a similar collection in America and sent it to London, where Dr. Williams gave it intensive study. This study proved inconclusive because few of the pictures were taken in the position necessary to show the required facial outline, full front, in repose.

A SPECIAL PHOTOGRAPH GALLERY

Immediately following Dr. Williams's arrival in America in November 1913 a photograph gallery was established in the Research Division for this particular work, a technic

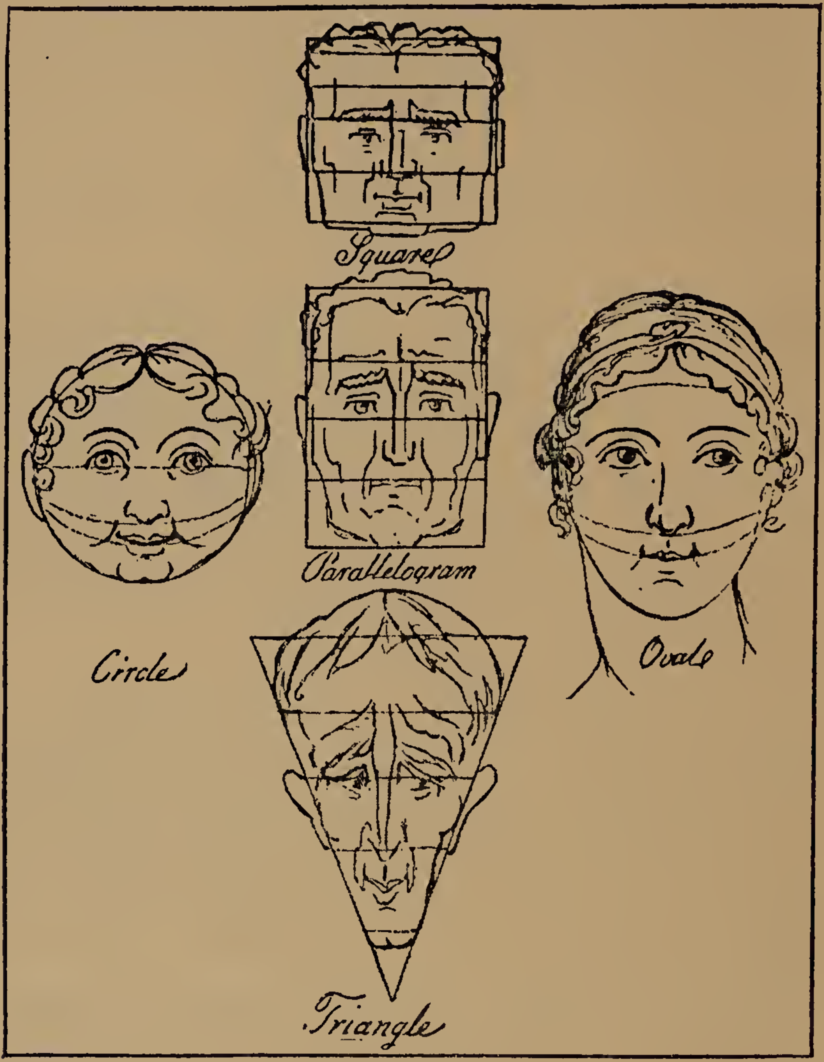

FIG. 93

This illustration from Dr. George H. Wilson's *Dental Prosthetics* shows diagrammatic illustrations of the typal forms of faces, as drawn by Madam Schimmelpenninck more than 100 years ago.

Of these diagrams those marked "Square" and "Parallelogram" are merely different lengths of the square type. Similar differences in length are found in teeth of the square type. The oval form is a combination of the Parallelogram and the Circle, the influence of the circular form rounding the cheek and jaw lines of the Parallelogram.

The form here marked "Circle" is of course exaggerated. Even the most pronounced forms of this type are more egg-shaped than round and are properly called "ovoid," meaning egglike.

for taking portraits in the position to afford the required information was developed, many persons were secured as sitters and a large number of portraits was taken, in some cases as many as six views of a single person in different positions likely to afford information. This gallery is still maintained and today, nearly twelve years after its inception, portraits of this sort are taken for further study. The gallery now has what is undoubtedly the largest collection of portraits to be found anywhere suitable for this particular purpose.

FORMULA FOR FACE CLASSIFICATION

In order to compare facial outlines in such way as to make classification possible, it was necessary to devise a Formula of Classification. The outline of the face below the condyles, when seen full front, in repose, was divided into the cheek line, which is usually the most important single feature, and the jaw line. The slope of the sides of the head (above the condyles), the roundness of the forehead, the width of the chin and the rapidity with which the sides of the face converge forward from the condyles to the prominences of the cheeks are all contributing factors. In some faces the cheek lines are so typical as to leave no doubt as to the type of face. But in cases where the cheek lines do not afford such striking evidence the other factors are taken into consideration about in the order in which they are listed above.

OUTLINE FORMS OF FACES LIKE FORMS OF TEETH

As the result of studies which extended several years after 1913, Dr. Williams and the author were able to establish the existence of faces of which the outline forms were practically identical with the outline forms of the teeth which Dr. Williams had carved, to show that they are among the most frequently seen forms of face and that they represent fairly well the entire range of modification in face forms. There were five forms in the square type, five in the tapering and four in the ovoid. (This number was afterward increased to six in the square and six in the tapering.)

DOES NATURE ACHIEVE FORM-HARMONY?

The discovery of practically identical forms in faces and teeth led at once to the query as to whether nature placed square teeth in square faces, tapering teeth in tapering faces and ovoid teeth in ovoid faces. Observation shows that in a comparatively small percentage of cases the outline form of the face and the outline form of the maxillary centrals are identical, that in a much larger percentage of cases the face and teeth are of the same type but not of the same modification, and in a small percentage of cases the face and teeth are of unlike types.

THE LAW OF PLEASING APPEARANCE

Then there followed a discovery which was fitting conclusion to all that had gone before: that the appearance is most pleasing, both only at a glance and on critical examination, when the outline form of the face and the outline form of the maxillary centrals are identical; that the pleasure in the appearance of the denture is lessened in proportion as the outline form of the teeth differs from the outline form of the face; and that when the face and teeth are of different types, the effect is unpleasing, even to observers who know nothing of the relation of face forms to tooth forms.

Here, then, was the perfect triangle—typal and modified forms of face scientifically determined and classified; identical forms in artificial teeth; and a simple law of harmony by which to determine which tooth form would give the finest esthetic result in any given face.

DR. BERRY ANTICIPATES DR. WILLIAMS

Dr. Williams was much surprised to learn, on arrival in this country, that Dr. F. H. Berry, some years before, had published an almost identical method for selecting tooth forms harmonious with face forms. Berry's method had but slight practical value at the time because there were no tooth forms which bore anything more than a conventional resemblance to face forms, and so selection, even by this method, left much to be desired. Dr. Williams's work was done independently, and it is interesting to note that it wholly confirmed Berry's work, greatly extended it and made it far more practical than it had been.

Practical Application of the Law of Harmony

The practical application of the law that the outline form of the maxillary centrals should be like the outline form of the face in repose is one of the few and happy instances in which the application is even simpler than the theory. It is necessary only for the dentist to invert the maxillary artificial central in the square and tapering types and compare the outline of the tooth with the outline of the face. By trying different teeth one at least closely harmonious with the face or capable of modification to be like the face will be found. The ovoid type in face and teeth is so evidently rounding in all characteristics that the harmony of outline is immediately apparent.

Dr. Williams's belief that in cases where the natural teeth had been inharmonious with the face form an improvement in appearance would be effected by properly selected artificial teeth has been strikingly supported by experience.

The months following November 1913 were busy ones for Dr. Williams. Much of the work which has been described in this chapter as if it were completed was still in the course of development and not very far along. He was so sure of the accuracy of what had been done that he desired not only to place the results before the profession but to present the evidence by which those results had been reached.

Dr. Williams Gives Private Demonstrations

He shared an office in New York with the author and to this office came a considerable number of distinguished dentists interested in what Dr. Williams was doing. He laid before each of them the evidence in hand and his conclusions therefrom. The author was present at practically all of these interviews. Not one of the dentists to whom the work was shown indicated by word or deed that he had ever heard of typal forms before. Some of them whom the Temperamental Theory had never satisfied were prepared to accept Dr. Williams's findings immediately. Others withheld decision until time permitted further study. No one offered any evidence in contradiction.

Dr. Williams Publicly Announces His Discoveries

On March 10, 1914, at a special meeting of the First and Second District Dental Societies, New York, Dr. Williams presented an overwhelming mass of evidence as to the fallacy of the Temperamental Theory of tooth forms, the existence of the typal forms in many of the races of men for several thousand years, the characteristics of the typal forms in faces and teeth, and the law of harmony between them, together with illustrations and descriptions of the forms in artificial teeth which he had evolved as representative of the range of modification in the three types he had discovered.

The outbreak of the war in Europe and the consequent world-wide emotional and intellectual upheaval naturally interrupted all forms of work, but, as opportunity offered, Dr. Williams and his associate continued to develop the knowledge of which he had presented the beginnings. By the end of 1915 the system of teeth and the basic information concerning it were sufficiently complete to permit a breathing spell. The theory of typal forms in faces and teeth and the law of harmony between them were generally accepted, and the teeth were coming into widespread and satisfactory use. Great improvements in denture technic, aside from tooth selection, were in progress and everywhere denture service was being put on a basis quite as scientific as that of operative dentistry.

The Search for Further Improvements

After a short rest Dr. Williams and the author started upon a new line of endeavor. While they considered the system of teeth, as it stood, to be the best that the state of knowledge at the time permitted, they declined to consider it perfect. They began a series of studies to see in what way it could be improved. Those studies have continued during the eight years which have intervened between 1916 and the writing of these words. They have involved every phase of tooth production. The success attained in former efforts has justified the Company in placing unlimited resources at their disposal. A technical staff of unusually high skill has been built up. Some idea of the detail in which studies have been carried on is indicated by the fact that in one line alone more than three thousand carefully planned experiments have been made.

It has been found impossible to make any changes in principle. The theory of typal forms in faces and teeth has successfully withstood every form of investigation as it has every test in practice. It would be premature to announce here what has been done, since the studies are not complete, but it is expected that the information will be presented in book form in the near future.

Unfortunately, during no small part of this last period of study Dr. Williams has suffered from progressively failing health, but with the force of utter devotion he has risen superior to it again and again.

CHAPTER XXI

DISSEMINATING KNOWLEDGE OF A BETTER DENTURE TECHNIC

IN SPITE of the fact that several years of extremely hard work intervened between the beginning of Dr. Williams's campaign for better teeth and the time when the improved forms, the system of teeth and the law of harmony between face forms and tooth forms were completed for presentation to the profession, Dr. Williams was inspired to continue his labors by the belief that when pleasing and efficient teeth were available to dentists, a scientific denture technic would be developed by the keen minds which would be attracted by the possibilities. Events have justified that belief, and coming generations of dentists will doubtless be trained to good plate technic as a matter of routine instruction. Dr. Williams's dreams were even more pregnant with possibilities than he imagined. This chapter tells the story of one phase of the development of the technic for which he had hoped.

* * *

When the book entitled *The Mechanical Side of Anatomical Articulation* reached some dentists who were earnestly seeking to render good plate service, they wrote the Company to the effect that they had been unsuccessful in mastering certain phases of the technic with only the text as a guide and asked where they could obtain personal instruction. As a result of these requests, a chair was placed in the author's office and instruction in the use of the face bow, the carving of the occlusal surfaces of the bite rims and the arrangement of the anatomical moulds to effect articulation was given to dentists who came for it. The number of applicants steadily increased until it became necessary to assign Dr. E. S. Ulsaver as instructor.

The advances in denture technic which Professor Gysi published in 1910 and which exemplified the principles to be applied to the formation of the occlusal surfaces of the new teeth made it highly desirable that at least some dentists in America should be made familiar with the discoveries. There was little hope that this could be done through the printed text, and so an arrangement was effected whereby Professor Gysi came to America and in September 1913 conducted two postgraduate classes, each of two weeks' duration. Dentists came from different parts of the country for membership in these classes. The following list of names, which may not be complete, is interesting now because every man who is still in practice has won local or national fame for fine denture work and many of them have become well-known teachers.

Dr. W. K. Bradfield, St. Petersburg, Fla.
Dr. D. D. Campbell, Kansas City, Mo.
Dr. G. W. Clapp, New York, N. Y.
Dr. W. E. Cummer, Toronto, Ont.
Dr. C. J. R. Engstrom, Los Angeles, Cal.
Dr. F. J. Fifield, Minneapolis, Minn.
Dr. F. W. Hergert, Seattle, Wash.
Dr. F. P. Moore, Hamilton, Ont.
Dr. H. A. Palmer, Greenville, Va.
Dr. W. Randall, Louisville, Ky.
Dr. W. H. Richards, Knoxville, Tenn.
Dr. J. P. Ruyl, New York, N. Y.
Dr. M. A. Schwartz, New York, N. Y.
Dr. C. J. Stansbery, Seattle, Wash.
Dr. R. W. Tench, Franklinville, N. Y.
Dr. B. F. Thielen, Paris, Tex.
Dr. W. H. Thompson, Cranbrook, B. C.
Dr. H. C. Werts, Beaver Falls, Pa.
Dr. W. T. Willard, West Toronto, Ont.
Dr. G. H. Wilson, Cleveland, O.
Dr. D. A. Zurbrigg, Philadelphia, Pa.

Among the dentists who assembled at New York for the purpose of taking instruction under Professor Gysi was Dr. Russell Wilford Tench, who was graduated some years before at Buffalo, N. Y., and had been practicing in New York State since that time. Immediately following the close of the classes Dr. Tench became associated with the Research Division of the Company for the purpose of continuing the instruction which had been going forward in the author's office and of improving it by applying what Professor Gysi had taught.

* * *

About the time that the members of the Gysi classes had become sufficiently familiar with the new technic to teach it to groups of their fellow-practitioners and before societies, the Research Division published the book, *Prosthetic Articulation,* which described in detail the Greene-Supplee methods of impression-taking, the classification of face forms and tooth forms, the law for selecting tooth forms, devised by Dr. Williams, and the methods of articulation which Professor Gysi had taught in his classes. Within about two years approximately thirty thousand copies of this book were circulated in the profession.

As the result of the teachings by Professor Gysi's students and the widespread publicity given to the new principles, the requests for instruction became more numerous. When those who inquired were informed that there was no school to which they could be referred for personal instruction, many of them wrote that since the Company had placed the vision of such achievements within their view, there rested on it a sort of moral obligation to help make it possible for men to turn that vision into achievement. They said further that while the colleges would doubtless care for the instruction of the undergraduates, it would be of decided benefit to the dentists in practice if the Company would assist them to secure the instruction they needed in the way a practitioner desired it. Many of them closed their letters with direct requests for personal instruction. The continuous interest of hundreds of dentists in the progressive clinics which had been given for the anatomical moulds confirmed the statements in many of the letters. The testimony of dentists who had been taught the Williams-Gysi technic and were applying it successfully was to the effect that such instruction would be a boon to every dentist who took it and to the patients whom he served. This testimony should be borne in mind in view of what developed later.

* * *

It was necessary to give some thought to the financial aspects of any plan for imparting instruction. The Company had guaranteed the expenses of the two Gysi classes and made up a deficit of $1300 which resulted from excess of expenditures over receipts from fees. Professor Gysi could not come to America to teach permanently, and no other teacher of equal fame was available. Office space was expensive, and so was equipment. On the other hand, dentists who desired to come for instruction faced heavy loss in closing their offices and in the expense for travel and hotel bills. A plan was devised whereby the Company guaranteed all expenses of equipment and maintenance, and a fee of slightly less than half the cost of instruction was charged each student. Patients were provided for whom the dentist-students were to make dentures.

A space sufficient to accommodate four dental chairs and the necessary work benches was, therefore, set aside in the Research Division, and Dr. Tench devoted himself intelligently and enthusiastically to the arrangement of the course and the instruction of dentists who desired to attend. Under these conditions he was able to make improvements in the application of the principles taught not only by the older workers, but by Greene, Supplee and Gysi. Some of these improvements have proved to be so important that they have become standard technic with the most advanced workers.

After a time the four chairs became insufficient for the accommodation of dentists who desired instruction. The Research Division secured larger quarters, which were properly equipped for the work. Eight chairs were provided and additional teachers were developed, so that there were three teachers to supervise the work of eight dentists. This insured nearly continuous personal attention to each practitioner during the two weeks required for him to receive preliminary training and to apply the principles by making a practical case for an edentulous patient.

* * *

In the summer of 1919 notice was served upon the Company that, under the dental law which had recently become effective in the State of New York, instruction of the sort being given could legally be imparted to dentists not registered in the State of New York only by a regularly chartered dental educational institution. From that date forward, dentists not licensed to practice in New York State could not be admitted to the Research Division for instruction in impression- and bite-taking.

* * *

It is interesting to note what had been accomplished up to this time and the conditions under which the work had grown. There had not been a word of advertising printed about the instruction and nothing had been written except in reply to inquiries addressed by dentists. Information about the work must have passed from mouth to mouth among members of the profession and must have been generally commendatory. Dentists came literally "from the uttermost parts of the earth," often at no small expense of time and money. At the time when the ban was placed upon students not registered in New York State, dentists had been admitted from Maine, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Florida, Alabama, Louisiana, Texas, Kentucky, Ohio, Indiana, Illinois, Michigan, Iowa, Nebraska, Kansas, Minnesota, Washington, Oregon, Utah, California, Canada, Australia, New Zealand, China and England.

At that time applications were on file from one hundred and sixty-eight dentists awaiting admission from thirty-seven states, the District of Columbia and Canada.

* * *

The ruling which excluded out-of-the-State dentists from instruction in impression- and bite-taking was severely criticized by many who were excluded, because the instruction had evidently made for itself a favorable place in professional estimation. However, it prompted many requests that teachers be sent to different localities, and in certain sections dentists undertook the work of organizing classes which would justify sending a teacher and defray the expense. In this way many dentists who would otherwise have had to come to New York received the information either at home or in localities more convenient to them and at reduced expense.

Dentists from the following countries outside the continental United States were members of classes: Australia, Brazil, Canada (Quebec, Ontario, Saskatchewan, Alberta, British Columbia), China, Chile, Dominican Republic, Egypt, England, France, Hawaii, Holland, India, Mexico, New Zealand, Norway, Panama, Paraguay, Porto Rico, Salvador, South Africa and Trinidad.

One or more members of the faculty of each of thirty-seven dental schools accepted membership in a class.

* * *

The teaching was carried on continuously for almost ten years, that is, from September 1913 to early in 1923. During this time approximately four thousand dentists received instruction. It is in every way probable that what they were inspired to do has materially hastened the reign of good denture technic of which Dr. Williams had dreamed and for which he had labored so diligently.

CHAPTER XXII

"A STUDY OF THE TEMPOROMANDIBULAR JOINT WITH SPECIAL REFERENCE TO THE FORM AND ACTION OF THE MASTICATING SURFACES OF THE TEETH"[1]

WHEN Professor Gysi published his tracings of the movements of the mandible and showed that the movements which these tracings exhibited could be reproduced only in an articulator which had two rotation areas located near the condyles, but not in the condyles, he introduced a subject which later became a veritable bone of contention. Certain dentists found themselves unable to agree with the locations of the Gysi rotation areas. They constructed articulators having a rotation area in the median line and set forth the articles of their faith with great confidence and vigor. So sharp and persistent was the discussion between the two groups that it threatened the development of a scientific denture technic, in which an annually increasing number of dentists was interested.

Dr. Williams became apprehensive that the main object—good denture service—might be lost sight of in the discussion of details and he set himself the problem of finding whether there was not some common ground on which the disputants might agree. His attitude cannot be better described than in one of his own opening paragraphs of the paper which he read before the National Society of Denture Prosthetists at New Orleans in October 1919. "There are differences and contradictions in these two methods of procedure, and while I believe that these differences, so far as they relate to results, are not so great as many suppose, it is not conducive to that unity of action on which real progress depends that antagonisms should continue any longer than is necessary to bring out the whole truth. Evidently when there are antagonisms or differences in theories, somebody is

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[1] Summarized from the *Journal of the National Dental Association,* 1921.

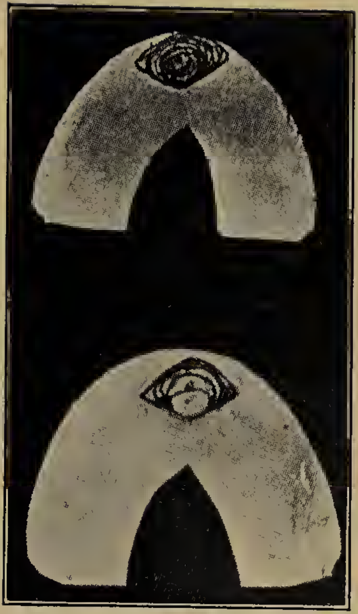

FIG. 94

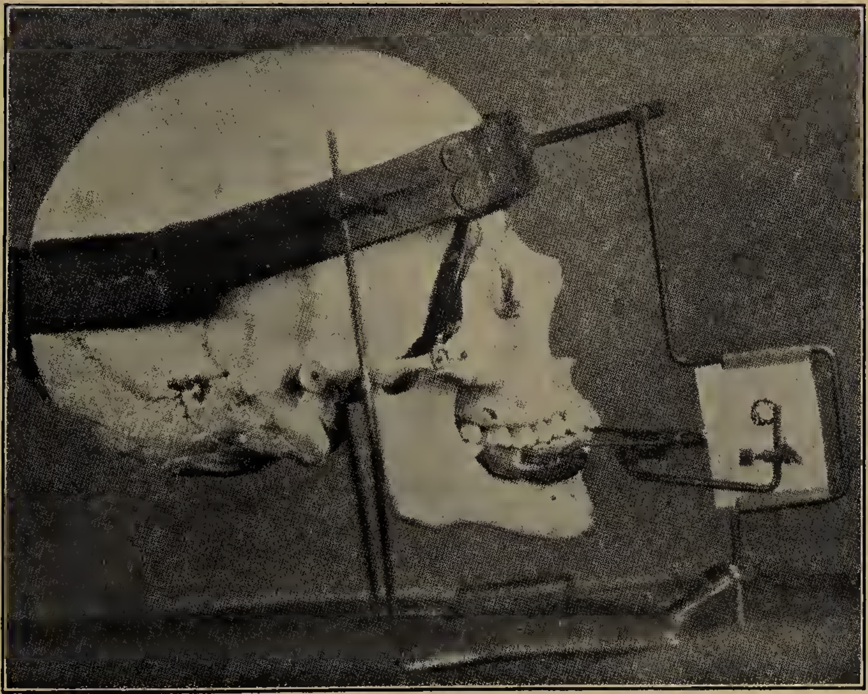

FIG. 95

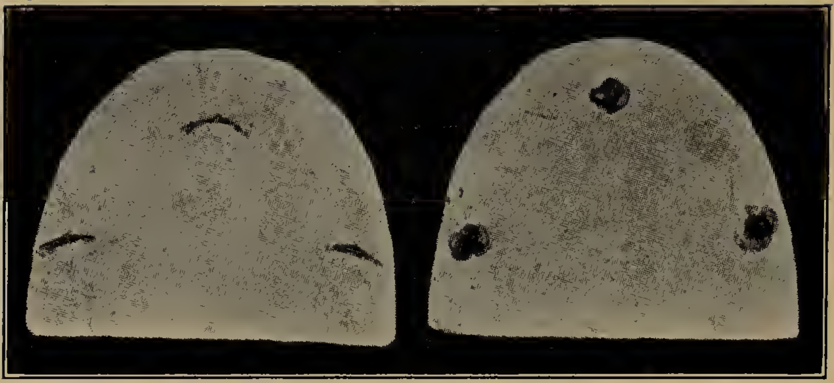

FIG. 98[1]

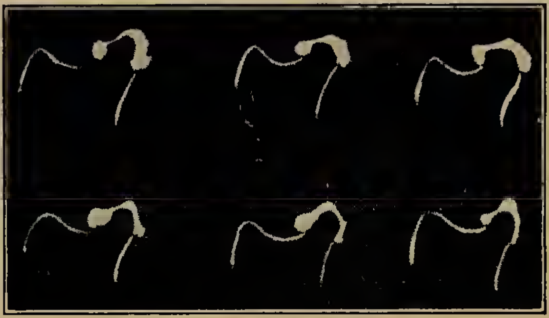

FIG. 101[1]

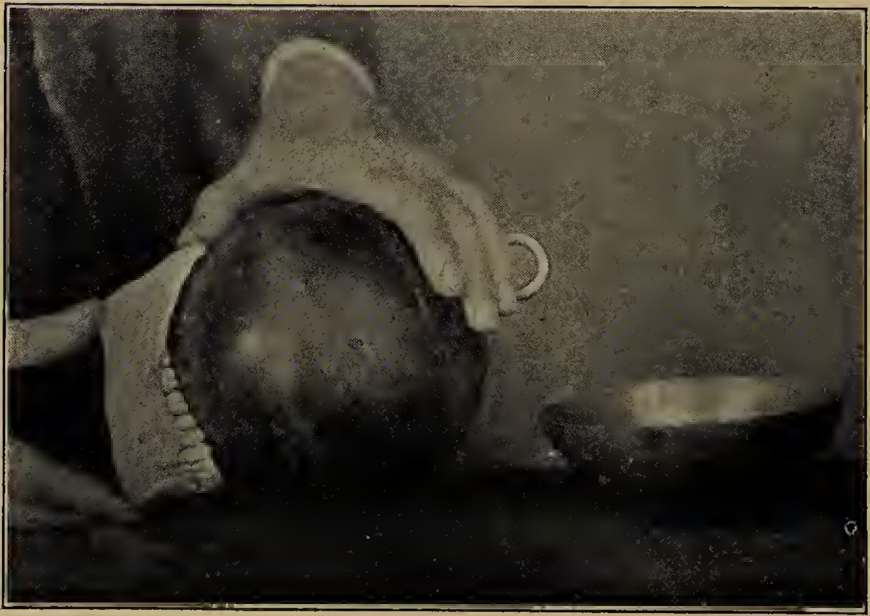

FIG. 102[1]

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[1] Exigencies of inserting the illustrations on this page necessitated placing them out of regular order.

mistaken. Somewhere there are unfounded premises or unwarranted conclusions."

As a part of his method of study, he devised ten experiments which he performed many times. For lack of space the results of these experiments are here briefly summarized.

Experiment No. 1

"To record, in a horizontal plane, the limits of movement of the lower incisor point with the teeth slightly separated."[1]

It was found that under the conditions set forth in the experiment the mandibular incisor point could trace a circle about a centimeter in diameter, and outside of this a diamond-shaped parallelogram, and within the parallelogram lines running in every direction. This experiment demonstrated three important things: (1) that the mandible has universal movement over an area equal to the diameter of the circle; (2) that the rotation point of the mandible is constantly changing during such movement; (3) that one can, at will, change the rotation points of the mandible so as to describe a circle and also what Dr. Gysi calls the "Gothic-arch" form of outline. "We shall see the full significance of this later, but it is seen at once that the jaw is capable of producing, in the incisal region, both of the movements, one or the other of which is claimed respectively by Drs. Hall and Gysi to be the true one." (Figure 94.[1])

Experiment No. 2

"To record, in a vertical plane, the limits of movement of the mandible with the teeth slightly separated."[2]

Under the conditions in this experiment it was possible for the recording device to trace the outline of a circle about a centimeter in diameter. (Figure 95.[2])

If the results of this experiment be combined with the results of Experiment No. 1, it will be seen that a point placed between the cutting edges of the lower incisors would touch any part of the surface of an imaginary sphere one centimeter in diameter.

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[1] *Journal of the National Dental Association,* 1921, page 276.
[2] *Journal of the National Dental Association,* 1921, page 277.

EXPERIMENT No. 3

"To record the condyle movements of an edentulous patient with a normal bite and the influence upon those movements of slightly opening the bite."[1]

Figure 96[1] shows the record of an edentulous patient, in lateral movement, made with the Gysi recording devices. The perpendicular lines represent the resting points. It will be observed that in the two sets of records, taken three days apart, the condyle, when in normal bite, moves only forward and inward from the resting position. When the bite is opened, the condyles have almost as much backward movement from the resting position as they have forward movement.

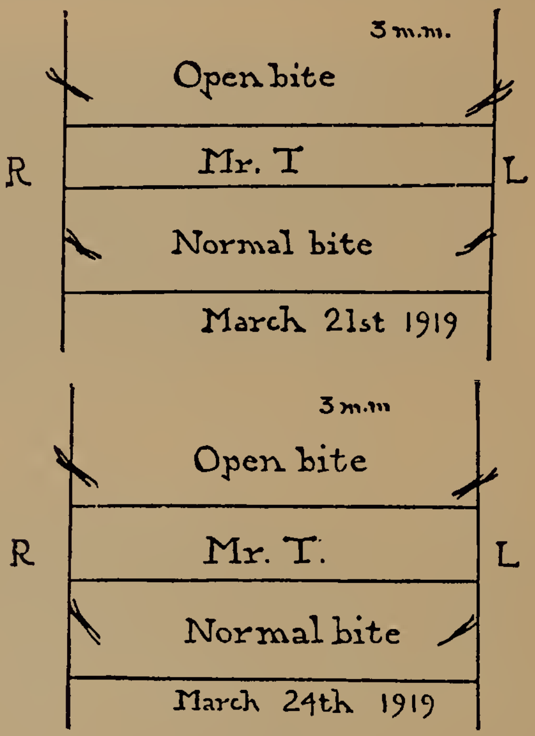

FIG. 96

EXPERIMENT No. 4

"To record the effects upon the condyle movements of opening the bite for an edentulous patient with condyle movements habitually unlike on the two sides."[1]

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[1] *Journal of the National Dental Association,* 1921, page 278.

This experiment, like No. 3, was made with wax bite plate with smooth rims. In normal bite the reproduction of the tracings required two rotation points, located at unequal distances from the median line, but near the condyles and posterior to them. When in the open bite, only one rotation point was required and that was much nearer the median line than were the other two. (Figure 97.[1])

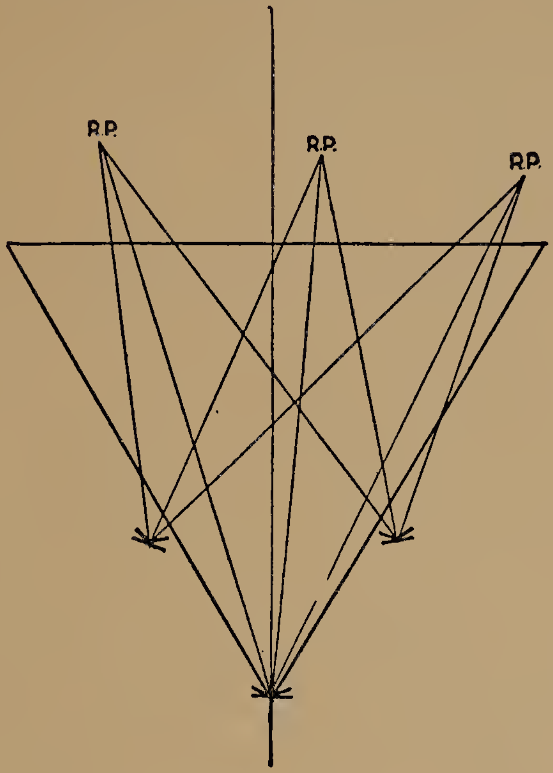

FIG. 97

EXPERIMENT No. 5

"To record, in a horizontal plane, the limits and direction of lateral movement of the incisor and first molar teeth."[2]

This experiment is performed in a manner similar to that in Experiment No. 1. Both the Gothic-arch form and the circular form of tracings have been recorded. (Figure 98.[3])

Experiment No. 6 is omitted from this summary.

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[1] *Journal of the National Dental Association,* 1921, page 278.

[2] *Journal of the National Dental Association,* 1921, page 279.

[3] *Journal of the National Dental Association,* 1921, page 279, upper half of Figure 6.

EXPERIMENT NO. 7

> *"To record, diagrammatically, the condyle movement resulting from the location of the rotation point at different places on the intercondyle line."*[1]

Figure 99[1] shows diagrams of the movements of the mandible with the rotation points and the rotation specified in each diagram. Dr. Williams called attention to the fact that there is practically no movement of the condyles in any of these rotation points. The triturating efficiency of the molars under such conditions will be but little more than with the direct open-and-shut bite.

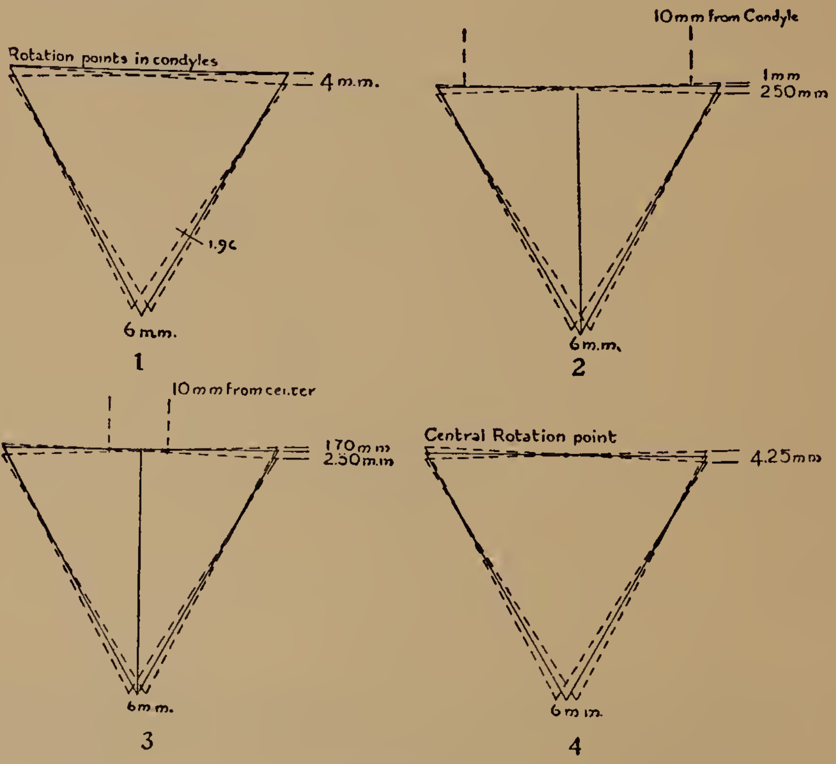

FIG. 99

EXPERIMENT NO. 8

> *"To record, .diagrammatically, the condyle movements which result from the location of the rotation point in the median line at different distances between the condyles."*[2]

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[1] *Journal of the National Dental Association,* 1921, page 281.
[2] *Journal of the National Dental Association,* 1921, page 282.

Figure 100[1] shows diagrams illustrating four locations of the rotation point in the median line. In the diagram with the rotation point 5 cm. behind the condyle line the lateral excursion of the mandibular incisor point of 6 mm. necessitates the lateral excursion of 3.48 mm. of the mandibular

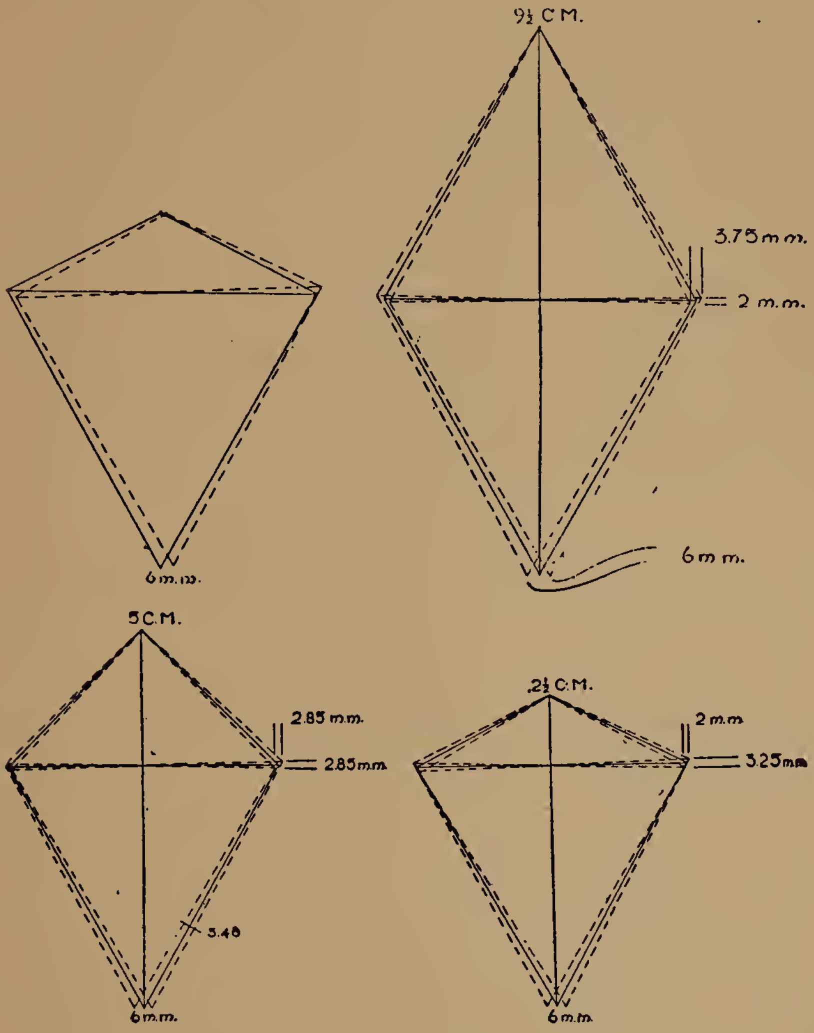

FIG. 100

first molar. When the rotation points are in the condyles, this lateral movement of the mandibular first molar is only 1.90 mm.

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[1] *Journal of the National Dental Association,* 1921, page 282.

Experiment No. 9

"To determine the relation of the articulating plate to the glenoid fossa in the resting position of the condyle."[1]

Dr. Williams measured skulls of a number of races in which the dentures were sufficiently good to insure normal resting occlusion. Impression compound was heated, pressed into the glenoid fossae, and the mandible forced into correct occlusion. After the impression material had hardened, it was removed and sectioned at the center in the antero-posterior direction. Very great variations in the form and size of the spaces between the condyles and the walls of the glenoid cavity were demonstrated. Much greater freedom of movement of the condyles existed in some skulls than in others. Figure 101[2] shows sections of the compound from three Eskimo skulls, in the top row, and from three European skulls, in the lower row. Much greater possibility of backward movement of the condyles from the rest position exists in the Eskimos than in the Europeans.

"It is evident now that the position of the rotation points or area is governed entirely by the amount of freedom of backward movement combined with lateral movement of the condyles." Dr. Williams then described the musculature of the mandible and the results of a number of special dissections which he had caused to be made. In the dissected cases he found it impossible to make lateral movements of the mandible without producing a certain amount of lateral movement of the condyle.

Dr. Williams concluded from this experiment that in the extremely small lateral movement which occurs when the planes of the cusps of the teeth are in contact in trituration the mandible also moves from a central rotation point. In the wider excursions of the mandible, made by the conscious effort of the patient, especially when made on bite plates with smooth rims, in which action of the movement of the jaws controlled by the cusps is not reproduced, the rotation point is forced out of the center of position toward the side. He called attention also to the fact that there may be two kinds of lateral movement of the condyles. One of these results from the location of the rotation points between or behind the condyles. There is also an independent lateral movement of the condyles when the entire jaw moves to the right or the left.

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[1] *Journal of the National Dental Association,* 1921, page 283.
[2] *Journal of the National Dental Association,* 1921, page 285.

Experiment No. 10

"To seek out that curve which will insure continuous contact of the upper and lower teeth in articulation."[1]

Dr. Williams determined the radius of the curve of Spee on one side of one skull to be 76 mm., on another skull 77 mm. and on another skull 78 mm. In measuring the lateral curve across the first lower molars by the aid of a special form of protractor it seemed that this curve agreed closely with the curve of Spee. He decided that the only form on which the lower teeth, for example, could move with perfect contact and with freedom in all directions would be a sphere the radius of which would be 76 mm. He prepared such a sphere and, removing the coronoid process and front of the rami from the mandible until the arc of a circle was completed from the second molar to the condyles, placed the mandible on the sphere and found, after removing a few imperfections in height of cusps, that the front of the condyles and all of the bicuspid and molar teeth were touching the sphere on both buccal and lingual cusps. Naturally, this contact remains perfect with any possible movement of the mandible. (Figure 102.[2]) It was perfectly obvious at once that here was the ideal form-curve to which artificial teeth could be set so as to give the most perfect contact of upper and lower teeth within the possible excursion of the mandible.

The examination of a few skulls in which the molar and bicuspid teeth were thrown out of contact during lateral and forward movements of the jaw shows that there were at least three causes for this displacement: (1) abnormal length or too great backward inclination of the incisal edges of the incisors; (2) abnormal positions of the bicuspids and molars; (3) (this last cause is the only one which concerns us at this moment) disharmony of the condyle path with the curve of Spee. When, by reason of the steepness of the front wall of the glenoid cavity, the prominence of the articular eminence or lack of sufficient development of the molar teeth, the arc of the circle in which the condyle moves is not homocentric or concentric with the curve of Spee, the molar teeth must be thrown out of contact with all forward movements of the mandible.

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[1] *Journal of the National Dental Association,* 1921, page 288.
[2] *Journal of the National Dental Association,* 1921, page 289.

To correct that condition is to solve completely the whole problem of securing perfect occlusion and articulation of teeth. The consideration of this problem is of equal importance to the orthodontist and the prosthodontist, but the difficulties before the orthodontist are greater than in the construction of an artificial denture.

A Device for Plotting the Segment of the Sphere

Dr. Williams then described two devices for plotting the segment of the sphere for each individual case. In each method a stout inelastic band passes around the head above the eyebrows and is fastened at the back. The front of this band carries a projection which is centered over the nose. To this projection is fastened a hinged arm which is so adjusted at the upper end that after having made its record on one side of the mouth it can be swung to the opposite side for making its record there. In the simpler device a pair of machinist's dividers can be used for the hinged arm. The trial plates are made, put in place and adjusted to proper height. The mandible is projected to the position of incising bite and the location of the head of the condyle marked on the face with a pencil.

A vertical mark is now made on the rim of the lower bite plate in the region which will be occupied by the tip of the cusp of the first upper bicuspid. The calipers are now adjusted so that with one end centered on the band the other end will touch the dot on the cheek. The calipers are then swung forward to cross the vertical mark locating the first upper bicuspid. The lips are then drawn back and the arc of a circle described with a needle point on the rim of the lower bite plate from the region of the first bicuspid to that of the second molar. This is repeated on the other side.

A series of metal shapes, which represent segments of spheres with radii ranging from 60 mm. to 85 mm., is kept on hand. From these the one nearest the radius of the individual case is selected, warmed and placed on the lower bite plate until it melts down to the segment of the circle placed on that plate. This melting of the rim of the bite plate should be very accurately done, as it is the most critical part of the whole operation.

The great significance of this simple method lies in the fact that the temporomandibular joint plays no critical part in the movement of the mandible after the cusps of the upper and lower teeth have come into contact.

The curve produced in this way is the basic curve of occlusion. It demands that the amount of overbite of the upper incisors should always be governed by the length of the cusps of the masticating teeth.

The rest of the paper contains a considerable amount of explanatory material related to articulators and depth of bite in artificial teeth which will be interesting to students of those subjects, but which it is impossible to reproduce here for lack of space.

* * *

"GEOMETRY OF MANDIBULAR MOVEMENTS"

At the meeting of the National Society of Denture Prosthetists in Boston on August 20, 1920, Dr. Williams presented a paper entitled *Geometry of Mandibular Movements* which was, in a sense, a continuation of the paper given before the same society at New Orleans. In preparation for this paper he asked the two questions: "Do the cusps of the teeth guide the movements of the mandible during mastication in a perfectly determined and fixed path, as the interlocking cogs of wheels guide movement, or is there considerable freedom of movement subject to the will or nervous reaction from stimulus? Was the record in my own mouth an exceptional one, and do mouths vary in this capacity for freedom of movement?" He regarded these questions as intensely practical.

Dr. Williams determined to secure accurate measurements of movements of the mandible in a large number of cases in living subjects. He worked over this problem for about two years, devising several methods and employing the aid of expert mathematicians and a machine invented by his son, Dr. Percy Norman Williams. He had reason to believe that the methods finally adopted were as near to mathematical perfection as will be reached in this work.

A full account of the methods, as given in *The Dental Digest* for May 1921, describes each step taken. At the time of reading the paper Dr. Williams had made sixteen records by the perfected methods. In four of these cases the rotation area was nearer the median line than the condyle during a slight lateral movement of the mandible, but when extensive lateral movements were made the rotation point, in all cases, was thrown into the condyle region.

* * *

Figure 103 illustrates the record from a mouth in which there is a fixed rotation for the lateral movement on one side throughout the complete excursion of the mandible. This point is about two inches behind the condyle. The first part

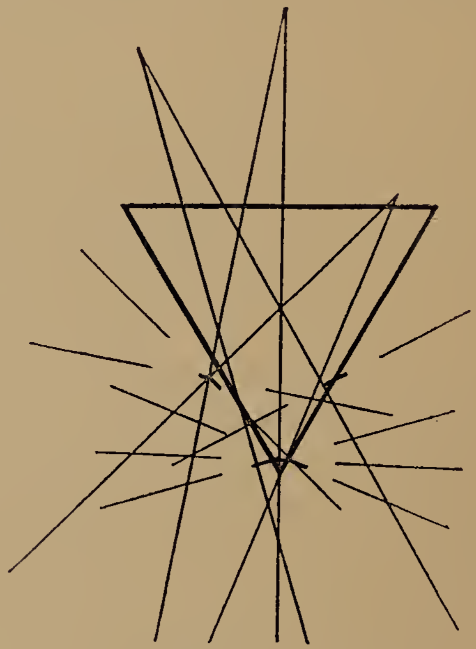

FIG. 103

of the lateral movement in the other direction shows the rotation point in the median line, but with the extension of the movement the rotation point soon changes to a location near the condyle.

Figure 104 shows the record from a case in which there was so much lateral movement of the mandible as a whole,

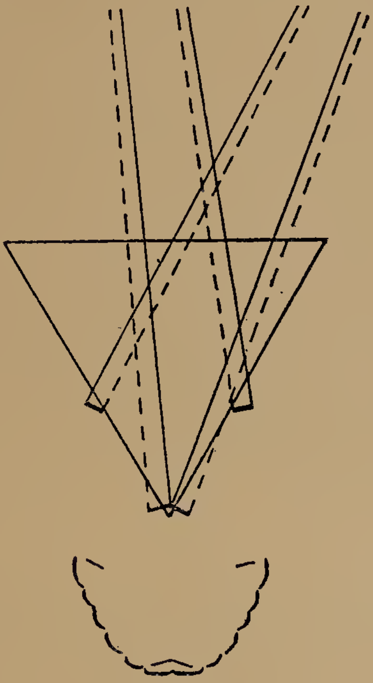

FIG. 104

that is, side slip, that the rotation points were thrown entirely outside the head.

* * *

After expressing his awareness that the number of these records was too small to permit final conclusions as to their bearing on articulator construction, Dr. Williams called attention to a few thoughts which had grown up in his mind about them. He believed it would be found that in a majority of cases in the so-called highly civilized races of today the glenoid cavities are deeper and more contracted, anteroposteriorly, than in more primitive people. Whereas the vigorous mastication characteristic of primitive people tends to develop a freedom of mandibular movement, with rotation area in or near the median line, modern methods of cookery and habits of mastication do not encourage freedom of mandibular movement, and there is undoubtedly an increasing tendency for the rotation areas to be thrown outward.

The facts so far unearthed seemed to Dr. Williams to have a direct bearing on the question of shallow-bite versus deep-bite teeth. He would expect to find shallow-bite teeth employed in a technic which allows the maximum freedom of the mandible, with the rotation area in or near the median line, and deep-bite teeth in a technic based upon the location of the rotation areas in the condyle regions. He concluded that the highest degree of success in the functioning of artificial dentures will be reached when there is considerable freedom of movement of the mandible in all directions, even when the upper and lower teeth are in contact. All tendency toward rigidity and the forcing of movements in one direction tends to cause irritation of the mucosa on which the dentures rest.

* * *

The conclusion from both of these papers seemed to be that when a technic is employed in which the bite is sufficiently closed so that the heads of the condyles rest in the deepest parts of the glenoid fossae, the rotation areas will be found in the condyle regions; but when the bite is opened so that the heads of the condyles are brought forward even a little upon the articulating plates of the fossae, the mandible is given much greater freedom of movement in all directions and the rotation area is moved toward the median line.

The choice between articulators with rotation areas near the condyles and articulators with a rotation area in the median line depends, then, upon whether the dentist wishes to work with an open or a closed bite.

PART FOUR

DR. WILLIAMS AS AN ANTHROPOLOGIST

PREFACE TO PART FOUR

DR. WILLIAMS did not regard his discovery of the typal forms in the teeth of man and the manlike apes as evidence that man has descended from the apes but as evidence that man and the apes have descended from a common ancestor. Somewhere in the dim past the line divided. The animals in one division remained apes; those in the other developed into man. The more Dr. Williams thought about those thousands of centuries in which the animals which developed into man were learning to walk upright, to use tools and to talk, the more he became filled with a desire to visit the places where remains of pre-man and prehistoric man had been found and, by a first-hand study of prehistoric skulls, to fill in the gap in his knowledge of what changes anterior tooth forms had passed through between the apes and modern man.

In beginning these studies Dr. Williams found it difficult to learn where to go and what to study. The knowledge about prehistoric man and his ancestors which has now become general was then confined to a comparatively few scientific men, and even among them it was much less extensive than at present. In order to obtain information with which to begin, Dr. Williams visited Professor Marcellin Boule, who is in charge of the Muséum d'Histoire Naturelle in Paris. This museum contains one of the finest collections of relics of very early times and has more prehistoric human skulls than are found in London. Dr. Williams obtained from Professor Boule certain directions as to what localities he should visit to get the best results.

Among the places which he decided to visit, the Neanderthal Valley near Düsseldorf, Germany, was accessible from London and offered a convenient point for beginning. In this valley and in other parts of Germany and France have been found many remains of prehistoric man and his prehuman ancestors, and from the study of these remains much about the development of the human race has been learned.

The areas surrounding the rock shelters under which man first took refuge and the caves which he later used have been occupied by scientists who specialize in studies of prehistoric man and who are exploring the locations which hold out the hope of further knowledge. Under the guidance of these experts plaster casts of the relics and skulls are made with such skill that they can hardly be told from the originals.

Dr. Williams was far from being satisfied with the restorations of prehistoric skulls as made in Europe and felt sure that there were comparative anatomists in America who made better restorations. That anticipation and belief have been fully justified by the splendid restorations made by Professor J. H. McGregor of Columbia University.

In the course of his journeys Dr. Williams made a fine collection of models of all the prehistoric skulls that were then known. These models, together with many tools and carvings, were subsequently presented to the American Museum of Natural History, New York, and became the foundation of what is now the finest known exhibition of remains of prehistoric man and restorations of ancient races, and, with the restorations made from these models by Professor McGregor, formed the basis of a large part of the work which was done by Professor Henry Fairfield Osborn in his classical book, *Men of the Old Stone Age.*

The results of Dr. Williams's studies were embodied in a lecture entitled *Prehistoric Man,* which was given, by request, before the New York Academy of Science; also, by special request, before the University of the State of New York, Albany, N. Y.; and, by similar request, before the National Dental Association at San Francisco in 1915. Some of the less technical portions of this address, greatly condensed, are reproduced in Chapter Twenty-five.

CHAPTER XXIII

THE NEANDERTHAL AND CRÔ-MAGNON RACES[1]

IN the year 1856 the bones of a human being were discovered in a grotto in the Neanderthal Valley. Through the ignorance of the workmen some of the bones were lost, but a scientist saved others and they became subjects of much scientific discussion, which appears to have been settled about the beginning of this century by the work of Schwalbe, who showed that the Neanderthals were not men in the modern sense of the word (Homo Sapiens) but the most important known missing link between the anthropoid apes and modern man.

During the fourth glaciation, a period which may have been from about 75,000 B.C. to about 25,000 B.C., various branches of the race now known as Neanderthal were scattered about in the part of Europe bounded by the Atlantic Ocean, the great glacier of the north which extended almost as far south as Hanover, Germany, the glacier of the Alpine region which extended northward almost to Basle and Munich, and the glacier of the Pyrenees.

The characteristics of the Neanderthals, many of which were very apelike, may be passed over rapidly. They were generally of less than medium stature, with short legs and long arms; they were incapable of standing quite erect; and their skulls, with few exceptions, were of rather small capacity. They are believed to have belonged to the period when man's progenitors were hunters and not agriculturists.

The period of the Neanderthal race probably comprises that stage of development in which these "men" first learned to avail themselves of the protection of overhanging rocks. During the period of their sojourn in Europe, probably about 50,000 years, they evidently developed enough to learn to conquer at least the animals which held the smaller caves and in these caves, thereafter, they lived. There the remains have been found, some of them arranged in what was evidently ceremonial burial.

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[1] A part of the information in this chapter is from *Men of the Old Stone Age* by Henry Fairfield Osborn.

* * *

Dr. Williams was unable to learn anything about the outline forms of the maxillary anteriors of the Neanderthals, but much is known of the characteristics of the other teeth. The posteriors were generally of large size, the roots were fused together and did not taper to the apices as rapidly as in modern races, but formed a broad, stout column. Osborn says that this characteristic alone would exclude the Neanderthal from the ancestry of the higher races. It is believed to have resulted from the habitual exercise of great force in eating raw food and in gnawing bones containing marrow, of which they were evidently fond. The pulp chambers of the teeth were very large and extended higher into the crowns of the teeth than they do in modern man. There were, however, many variations in the teeth during the long period that this race lived in Europe. The dentition of the Old Man of La Chapelle-aux-Saints, one of the most famous of all the Neanderthal skeletons, is said to be human in character, though extraordinarily massive. In other specimens the teeth are small, and in some the roots of the molars have been more or less absorbed.

In the opinion of most students the Neanderthal race did not develop from a lower race which preceded it in Europe, nor did it develop into a higher race. It did not give birth to its successors. It probably migrated from the cradle of the race, perhaps in Asia, and was later succeeded by another migration. As the result of what was probably the most sudden and extensive racial change in the prehistory of Western Europe, the Neanderthal race entirely disappeared, perhaps about 25,000 B.C.

* * *

From Düsseldorf Dr. Williams went to Bordeaux and there took a private automobile into the interior of Southern

France. He visited the caves at Les Eyzies and went from there to La Chapelle-aux-Saints, where the Old Man of La Chapelle-aux-Saints was discovered. At the caves of Les Eyzies he found many interesting relics of the race which probably followed the Neanderthals.

The Neanderthal race may have been driven out or exterminated by a race of men (Homo Sapiens) of superior stature, much more highly developed and of an intellectual capacity perhaps equal to that of man today. This race was known as the Crô-Magnon. It probably developed in Asia and reached Europe by migration along the shores of the Mediterranean. Supposed descendants of this race now occupy a limited area in Central France.

The Crô-Magnons, upon their advent into what is now France, probably about 25,000 B.C., found the climate cold and what we should call disagreeable. They appear to have promptly taken possession of the caverns, possibly by the simple expedient of killing the former inhabitants, and these caverns probably formed the centers of what may have become a rather densely populated community life, so that the bigger caverns may have sheltered large numbers of people for a long time. This was made possible by the fact that the Crô-Magnons appear to have possessed oil lamps and could therefore light the dark portions of the caverns, which the Neanderthals could never do.

In some of the caves the Crô-Magnons left evidences of a degree of intelligence which has astounded students. On the walls of caverns, in parts always dark except under artificial light, sometimes as far as 1800 feet from the entrance, they painted pictures of some of the animals they encountered, sometimes in three colors, black, red and yellow. The reasons why they painted are unknown. It may have been the joy in expressing a developing faculty, a part of some religious or magic rites, or merely to while away time. But whatever the reason, the drawings and paintings steadily improve in quality until those which were made last exhibit a degree of fidelity and vivacity quite equal to that in sketches by the best modern artists. In addition to the paintings they made many carvings on ivory and bone.

The dentures of many of the Crô-Magnons were fine in arch form, in arrangement of the teeth and in the forms of the individual teeth, which often exhibit all the delicacy and beauty found in modern teeth. Dr. Williams was unable to obtain many maxillary centrals, but he learned that the double curve on the mesial surface of the maxillary laterals, which some dentists have thought to be indicative of nature's plan to eliminate these teeth, is found in the laterals from this race of many thousands of years ago. Dr. Williams was able to obtain reproductions of several Crô-Magnon skulls, a number of stone tools, and etchings on ivory and bone.

CHAPTER XXIV

THE PILTDOWN SKULL

IN 1911 there was exhumed on Piltdown Common, England, by Mr. George Dawson, a portion of a frontal bone of what may have been a human skull. The next year, in the same location, there was found one-half of a mandible with two molar teeth in position, a parietal bone and an occipital bone. Later a single-rooted tooth, larger than any known human cuspid, was discovered. While these bones were at no great distance below the surface, the condition of the bones, the facts that the flint implements unearthed at the same level were of the rudest type and that in the same layer were found bones of animals which may have been extinct in England for more than a thousand centuries indicated that if the bones were human, they were relics of a time very early in the history of the race, perhaps about 150,000 B.C.

The skull, which may be that of a female, is about medium in size. The bones are very hard and excessively thick. The forehead is steeper than that in skulls of the Neanderthal race, and the ridges above the eye sockets are less pronounced. Certain characteristics of the skull indicate that the portion of the brain controlling articulate speech was very little developed.

The mandible, about which raged that portion of the discussion in which Dr. Williams and dentists generally are most interested, is much more primitive in character than is the cranium. This is considered by some scientists to be a normal condition, because the growth of the brain that had to preside over the refinement of the features and of the bodily character in general is not like the development of a muscle by exercise, but is the building-up of the most complex mechanism in existence.

The development of the human brain out of the brain of the primitive and unknown ancestors has required that the area of the cerebral cortex should be developed to be three times as great as in the manlike apes. It is probable that this required a very long time, so that the evolution of the cranium toward the characteristics found in Homo Sapiens may have long preceded the development of human characteristics in the mandible. The molars in the mandible are human in character and very large.

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Through the courtesy of Dr. Woodward of the Natural History Museum, South Kensington, Dr. Williams was permitted to see the fragments and make photographs of them before any account of them was published. When Dr. Woodward's first restoration was made public, Dr. Williams called the attention of Sir Arthur Keith, Hunterian Lecturer at the Royal College of Surgeons, to the facts that Dr. Woodward had made the lower incisors wider than the maxillary incisors and that he had established relations between the maxillary and mandibular cuspids that made lateral movements of the mandible impossible. He suggested to Sir Arthur that he make a critical examination of the whole restoration. Sir Arthur did this. He accepted the views which Dr. Williams offered as to what the dentition should be and asked Dr. Williams to make a restoration of the dentition which he could exhibit in connection with a restoration of the cranium which he proposed to make. Dr. Williams restored the dentition of both jaws. He gave the teeth characteristics which he believed to be halfway between simian and human and which permitted lateral movements similar to those that must have worn the occlusal surfaces of the molars.

* * *

At the meeting of the International Medical Congress in London in 1913 Sir Arthur Keith presented the restoration of the cranium which he had made and in connection with it the restoration of the mandible which Dr. Williams had made at his suggestion. Dr. Williams, by invitation, then presented his criticisms of the dentition of Dr. Woodward's restoration and the reasons in support of the dentition which he had made. He called attention to the fact that there was no known skull, animal or human, in which the mandibular incisors were wider than the maxillary incisors and that an interlocking relation of the maxillary and mandibular incisors prevented lateral movements, which were evidently habitual in the Piltdown man.

"The hypothesis which is accepted by nearly all the foremost authorities on this subject is that both the anthropoid apes and man have arisen from a generalized common ancestor; that since their origin the specialization of each has become more and more marked . . . the gorilla branch has become more and more gorillalike. Man has sacrificed certain primeval qualities to become more human, while the gorilla has retained certain qualities which were once a great advantage but which have prevented him from becoming human. Let us see how that hypothesis applies to the teeth. The generalized ancestor started with teeth that were somewhere midway between the present anthropoid and human dentitions. We have suggestions of that form in the fossil apes Dryopithecus and Pliopithecus, which have been referred to by several authorities as the possible generalized ancestors of man and the apes. My claim is that any being in the human line of descent of half a million years ago would, according to this hypothesis, have had teeth as closely resembling the human teeth of today as the teeth of an ape of 500,000 years ago resemble the teeth of the gorilla or orang of today. If that reasoning is sound and in accordance with all that we know of the way in which evolution works, then there is not the slightest warrant for the form Dr. Woodward has given to the teeth in his restoration."[1]

The audience examined the restoration closely and listened to the arguments in its favor. No one offered anything in rebuttal. In recognition of the contribution which Dr. Williams had made to the knowledge of the anatomy of the Piltdown skull he was elected a Fellow of the Royal Anthropological Institute of Great Britain and Ireland.

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[1] From Dr. Williams's paper entitled *Prehistoric Man.*

CHAPTER XXV

"Prehistoric Man"

"MAN has always been curious about his origin and prolific in the invention of legends to explain it. All of the great nations of antiquity and most savage peoples have their mythical stories of how they came into existence, and these myths or allegories constituted the generally accepted explanation of man's origin until a time within the memory of many now living.

"Nearly all that is known of ancient man has been discovered within the past fifty years and the larger and more important part of our knowledge on the subject has come to light during the last half of that period.

"Probably the chief reason why systematic investigation of this great problem was so long delayed is to be found in the gradual abandonment and almost complete disappearance of the evolutionary idea which Aristotle had proclaimed and which even the Fathers of the Church received with more or less favor. But the doctrine of arbitrary creation was more in harmony with the later policy of the Church, and when this doctrine received the powerful support of Milton's great poem it became the almost universal belief.

* * *

"Nature is never in a hurry. Are a hundred centuries necessary for producing a slight change in the color of the skin, a little modification in some nervous adjustment? Very well, we will take a hundred or five hundred centuries for it. Nature seems to take the purely philosophical view of time, that it is an illusion and has no real existence. And it really must be so if there is anything corresponding to our conception of intent or purpose back of phenomena. It is the end, the result, that matters, not the centuries taken for its accomplishment. . . . Is this view not more consonant with the highest ideals we can form of an infinite and benign wisdom than the theory that man was created from the first as perfect as he could be made but not quite perfect enough to prevent a considerable proportion of his descendants from becoming ever more and more degraded? A creation which is an ever increasing success surely reflects infinitely more credit on the creator than one which is a perpetually increasing failure. The more advanced of our religious teachers have accepted the doctrine of evolution in a general way, but there are still many who hesitate over some of its logical conclusions, particularly as applied to man. But the time has arrived when they must choose fully and completely between the old and the new points of view. It is a matter of the most profound practical importance for us to know whether man has *de*scended to his present state from the level of a superman or whether he has arisen and evolved from the level of the brute. If man has fallen from some former state of pristine purity and lofty intelligence to his present condition, then, truly, there is no hope for him except in an everlasting succession of miracles; but if the position he now occupies represents the advance he has made in a million years from the level of the ape, then no intellect can grasp, no imagination can picture the height on which he may be standing a million years hence. There are those who still think that the theory of evolution degrades man. Rightly understood, no teaching has ever so much exalted him. And that is the point of view from which I propose to consider this subject. In laying before you what I believe you will concede to be overwhelming proofs of man's evolution from a very lowly condition I feel sure you will find in that evidence the greatest promise, the most substantial hope for the future of humanity. If the destiny of man is being minimized today it is not science that is doing it. There is a point of view, held by many of the ablest men of our time, poets, philosophers and scientific workers, from which the teaching of evolution, with all that it involves, may be regarded teleologically.[1] I believe that the final harmonizing of science with religion will come from the development of this point of view. From this outlook the life force which has produced man is contemplated as not only active and functioning in matter from the beginning but also as continuous throughout all time. . . .

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[1] *Teleology* is "that character of nature showing itself in rational and purposive adaptation."

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"We now have a very considerable number of the most profound thinkers of our time, men of genius like Sir Oliver Lodge, the great psychist; Bergson, the philosopher; and Henri Fabre, the king of entomologists, the 'Homer of the Insects,' as Maeterlinck has called him, who believe the great underlying principle of nature is the 'increasing purpose,' as Tennyson so forcefully expressed it. That 'increasing purpose,' beginning with the slime of the old Cambrian seas, has arrived at the man of today. Truly, the record of that long journey is an infinitely more wonderful story than the ancient legend-makers ever dreamed of. . . .

* * *

"The sources of our knowledge of prehistoric man may be arranged in several groups—the nature of the deposit in which his remains are found, which indicates the period or era in which he lived; the tools and instruments found associated with his remains in cavities or in the same geological strata, which show the degree of his culture and skill in the practical affairs of his life; the architectural remains and earthworks which have survived the ravages of man and time and tell us something of his customs in disposing of his dead, and also of his religious ideas, and of his methods of defending himself and his flocks and herds against his animal and human enemies.

"To these sources of information should be added the relics of his art work, which are often of a high degree of merit and convey considerable knowledge about certain features of his environment, particularly about some of the extinct wild animals which he knew and hunted and the bones of which are often found associated with his own. . . .

"There are two sources of information from which we have learned much about primeval man—his flint implements and the records of the Great Ice Age or Glacial Period in Europe. . . .

"Two things especially distinguish man from the animal world below him—speech and the use of tools. The industrial history of man could be perfectly portrayed by illustrations of his tools and implements. From a stone axe to a steam engine, from a flint arrowhead to a machine gun, from the flint graver with which he expressed his thought and feeling on mammoth tusks and reindeer horn to the modern printing press—there is the whole record of man's material advance. In our study of prehistoric man what strikes us at first as an appealing fact is that out of the very moderate estimate of half a million years during which man has been making tools the advance which has resulted in modern civilization has nearly all occurred in the last ten thousand years. And a fact which is only a little less surprising is that nearly every invention fundamental to modern civilization was in existence ten thousand years ago. . . .

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"There were progressive and backward people in ancient times as there are today. When the skillful people of the valleys of the Dordogne and the Vézère in Southern France were producing those wonderfully worked laurel-leaf patterns of flints, there were other localities where the implements in use were of the crude, coarse type of the Acheulian or the Chellean period. There are native tribes of today who are still living in the Stone Age. And on that point I have something of very curious interest to tell you. In the town of Brandon, in Norfolk, England, the making of flint tools and weapons is still carried on as an industry that has descended, it is believed, with an unbroken record from prehistoric times. That, I think, may be claimed as one of the most remarkable facts in human history. . . .

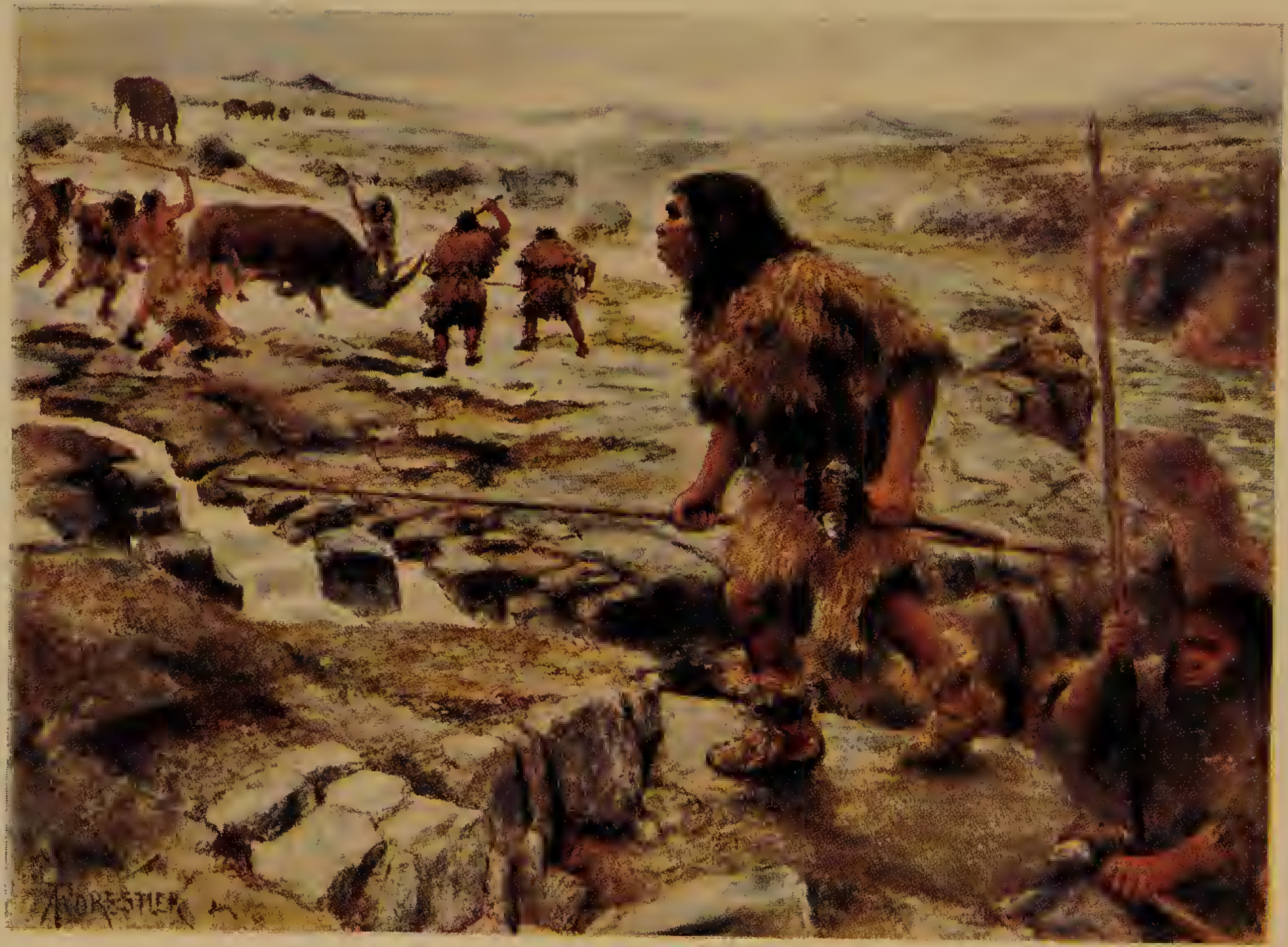
"The Great Ice Age, or the Glacial Period, began in late Pleistocene times and continued with fluctuations throughout nearly the whole Pleistocene era. It therefore covers nearly all the period allotted to prehistoric man so far as we know of him at present. He must have existed, even as a tool-making animal, earlier than this, for relics of his work have been found in various places. . . .

* * *

"There is one other preliminary consideration to which I must ask your attention for a moment before we come to the real substance of our lecture. Usually the first question any person asks on being shown a prehistoric skull is, 'How old was he?' That, in most instances, is the most difficult question to answer with any degree of certainty that can be asked. An answer can usually be given in terms of geological time, but that form of time takes no very accurate account of the years or centuries. But the facts are fast accumulating which will make more accurate statements possible. The tendency at present is, as Professor Osborn has recently pointed out in his very scholarly work on *The Age of Mammals,* emphatically in the direction of increasing the duration of Pleistocene time, the period which contains nearly all of our known evidence concerning early humanity. One of the latest statements on this deeply interesting problem is by Penck, a great authority in this field. He asks for a minimum time of 500,000 years for the duration of the Great Ice Age with a possible extent of over 1,000,000 years. He thinks that from 30,000 to 50,000 years have elapsed since the close of the Glacial Period while other authorities claim 100,000 years have passed since the last retreat of the Glacier began. . . .

* * *

"I have several times during the course of this lecture referred to the irregular course of human evolution. It is, of course, possible, even probable, that if a sufficiently large number of skulls of all ages could be found we should see that development from low to higher types had been very gradual. But that is not exactly what I mean by regularity



THE RHINOCEROS HUNT.

From a painting made especially for Dr. Williams's lecture by A. Forestier.

or irregularity in evolution. If we take the Neanderthal race we shall see, from the material for study which we now have, that there has been a very gradual evolution of the type, but we also observe the union in individual specimens of very high and low characters. We have in the Man of La Chapelle-aux-Saints, for illustration, several very strongly marked anthropoid features united to a skull of very large brain capacity. Man evidently threw off some of his apelike characteristics much more rapidly than others. Now we have a very striking illustration of this course of evolution in the Piltdown man, for here we have the most anthropoid human lower jaw ever discovered united to a well-developed cranium, which, according to Professor Keith, has a larger brain capacity than the present-day average. . . .

"This is the most revolutionary discovery concerning ancient man that has ever been made. It seems strongly antagonistic to some of the most fundamental principles of the Neo-Darwinian school of evolutionists. The least that can be said about it in this connection is that it forces on us one of two conclusions—either the modern type of man, represented by the finely developed upper portion of the skull, is enormously older than any one had previously supposed or the modern type of man appeared suddenly by a leap according to the mutation theory of de Vries. But even if we accept the former view and so go back to those earlier views of Darwin which he more or less abandoned in his later writings, we still have to face the fact that if the Piltdown skull is no more than 500,000 years old, at least a million years must have been required for the evolution of so finely developed a cerebrum, which is still united to a lower jaw more anthropoid in all its features than we believe the mandible of that generalized ancestor of both man and the modern apes to have been. It is also a striking confirmation of the view that man attained the supremacy of his position in the animal world by brain development while he was still closely related in many other features to his anthropoid congeners. In addition to this the Piltdown skull contains the strongest proof ever presented that whatever the cause of variation may be it does not necessarily produce immediate adjustment or harmonious developmental relation between the different parts of an organism. The brain of a modern man united to the jaw of a gorilla is the most astounding fact in the history of anthropology. . . .

* * *

"The far-off simian ancestor of humanity was probably a helpless creature compared with many of the species by which he was surrounded and some of which preyed upon him. At first he probably lived on the ground, but to escape extinction he took to the trees. . . . Once in the trees he was obliged to assume the upright attitude to a much greater extent than when on the earth. This led to other very important changes. The weight of the body, being thrown onto the hind limbs, the anatomy of the legs and spinal column slowly changed and this part of the body became better and better fitted for the upright position. Coincident with these changes still more important ones were in progress. The fore limbs, freed from their functions for assisting locomotion, began to perform a variety of uses under the more immediate control of will. This in turn reacted on the further development of the brain. We are only just beginning to understand and appreciate the enormous value of the training of the hands in assisting brain development. With our simian ancestors all this became, from necessity, a more or less spontaneous development. When he started on his arboreal career our ancestor was probably a small animal perhaps half the size of a chimpanzee. But the constant reaching which the conditions of his tree life imposed upon him undoubtedly stimulated growth, and such a stimulation continued for thousands of years would probably affect the germ plasm and establish heredity qualities. Natural selection accomplished the rest, and when he finally emerged from his long arboreal retreat and made the solid ground once more his partial place of abode he had become a far larger and altogether much more formidable creature. And he had added size and activity of brain to strength of body and limbs. For his diet he probably preferred fruits, nuts and certain succulent roots and tubers, but he could, on occasion, rob a nest of either eggs or young birds or indulge in an hors d'oeuvre of insects. He sometimes made use of a stone to crack the shell of his nuts or to assist in tearing away the hard earth over some favorite root or tuber. In cracking his nuts he would sooner or later learn the value of an anvil stone on which to place the nut. Then, in striking it, he would sometimes splinter off a part of his hammer stone and learn that the piece which he still held was sharper and more efficient for several purposes. This would suggest the voluntary splintering of a hammer stone when a sharper edge was needed for some particular use. It might have taken a hundred thousand years for him to learn that he could sharpen and so make more efficient a hammer stone. But once that lesson was fully learned the great highway that led straight on to the status of humanity and modern civilization lay open before him. If there is any definite point in his long career when or where the animal became man it was when he, for the first time, deliberately and with intention converted a natural stone into a tool of his own design. . . .

* * *

"If the Great Ice Age had occurred at an earlier period in man's evolutionary career it would probably have either caused his extinction, as it caused the extinction of certain species of animals, or driven him south where the conditions would not have stimulated further development. But man had reached the stage to benefit by what happened. Up to this time he had probably wandered about in family groups, a naked, very hairy and altogether very primeval savage, able to live without much mental effort. He had no fixed abode and but little need for other than temporary shelter. With the oncoming of the Glacial Period important new necessities were increasingly felt—the need for a new food supply and for clothing and shelter. His fruit and vegetable supply of food would steadily decrease and animal food would take its place. The skins of the animals would be thrown over his shoulders for protection during the colder storms. There would be a growing tendency to resort to rock shelters and caves during the more inclement periods of weather. As these shelters were limited in number and accommodation space he would of necessity be brought more and more into contact with his fellows. In the killing of animals for food supplies they would soon learn the great importance of concerted action. . . . And thus would be established the first cooperative efforts, the central principle of all social and civilized life. We know that in early palaeolithic times man hunted the rhinoceros and the huge mammoth, a beast larger than any existing elephant, and both very dangerous animals. Mr. Forestier's picture of the rhinoceros hunt is no doubt a spirited representation of an actual event. . . . It must have been during the Great Ice Age that man made another discovery, and this the most important in all the annals of human development and social progress—the discovery that he could produce fire at will. Man had probably always known fire and made use of it for a long time before he found out how he could produce it whenever he wanted it. In the making of his stone implements he was certain, sooner or later, to use a hammer stone of iron pyrites on his flint. The resulting sparks would sometimes ignite dry combustible material into which they would fall. I think we may be certain that such a phenomenon produced on prehistoric man as profound astonishment as he was capable of feeling. Once he had fully grasped the situation he would make the experiment over and over for the sheer delight of exhibiting his newly acquired power. . . . The producing of fire by friction was also a discovery of primeval man. . . .

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"We are beginning now to see something of the profound effect which the Great Ice Age produced on primeval man. It stimulated all his faculties by forcing upon him increased exertion in every direction. It compelled him to make clothing and to seek shelter. The making of clothing was the beginning of industry and the necessity for shelter inaugurated the commencement of social life. This social life was greatly promoted by the discovery of the ability to make fire at will. The camp fire was primeval man's club, salon and domestic hearth all combined in one institution. As the palaeolithic era draws toward its close the cold increases and the hairy mammoth first, and later the reindeer and other arctic animals, indicate the severity of the climate. And this is just the time when prehistoric progress is most rapid. Greater advance was made during the Solutrian and Magdalenian periods, a comparatively short time, than during the previous hundred thousand years. Man was no longer the creature of his environment; he was becoming its master. His physical evolution as a species had long been completed, his moral and spiritual evolution was beginning. The first necessary step in that great work was the conquering of external nature, and in that work his greatest ally, his powerful and indispensable friend, was *fire.*

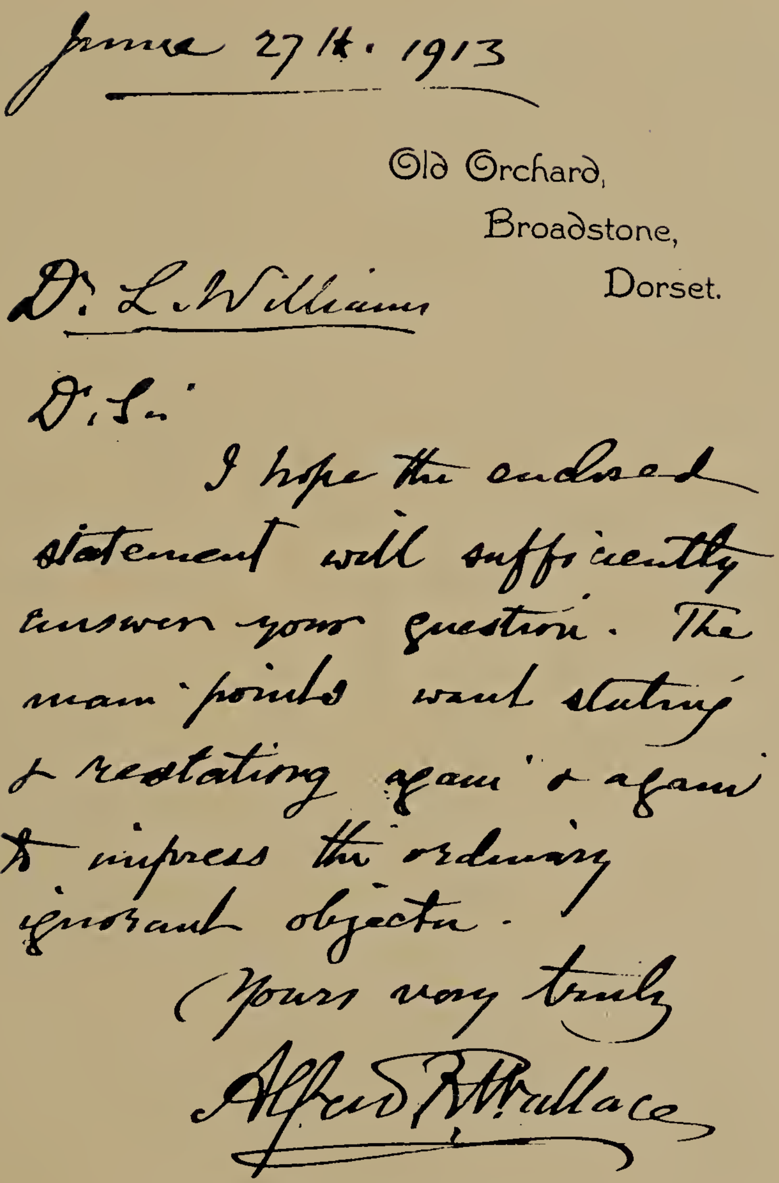
* * *

"I have spoken of man's physical evolution as completed, meaning, of course, that no further physical change is anticipated which will remove him from the position he now occupies in the order of Primates and no change which will give rise to a new and higher family in that order. Does this mean that the principle of 'natural selection' has ceased to be operative with him? Not entirely, for natural selection works in the improvement of species; in fact, it may sooner or later appear that this is the chief field of the activity of this law and that some other principle is largely responsible for the origin of species; but it also means that since the mind of man became a dominating factor in his evolution it has largely neutralized the effects of natural selection even in the improvement of species. Very intimately associated with the doctrine of natural selection is the theory that the human family arose from a single pair of individuals.

"This is the teaching of so great an authority as Professor Keane in his book on ethnology published as late as 1909. . . . Being very desirous of hearing the views of Dr. Alfred Russel Wallace as to the bearing of the doctrine of natural selection on this question of man's origin, I wrote him asking for an interview, which he kindly gave me. . . . I went down and spent a memorable afternoon with Dr. Wallace at his charming Dorsetshire home. But so many interesting points came up for discussion that afternoon that I never succeeded in getting a quite satisfactory answer to the one question I most wanted his opinion on. Soon after my return I wrote him asking among other things whether, in his opinion, the appearance of humanity could ever have depended on the survival and variation of a single pair of ancestors. . . .

"A few days later I received a reply, accompanied by the following statement:

> It is not easy to make the ordinary reader understand such a question as to variation as you put to me. It can perhaps be best explained by a reference to very familiar cases with which everybody is acquainted.
>
> Everyone who will think over the subject of variation among the men and women he sees around him will be surprised at the wonderful differences, not only in the larger characteristics such as height, weight or complexion, but also in every single part that can be easily observed such as the length or shape of the head, ears, nose or eyes, the length of the legs, arms or fingers, and especially the proportion of all or any of these parts to the others. He will find all these to vary in a most unexpected degree and very often each one seems to be quite independent of all the others. The result is that if you could examine a large number of any one race or variety of man, and if the question were as to the modification by selection of any one of these numerous characters, the whole population of that race, consisting perhaps of many millions of individuals, could be divided into two portions consisting of those in which the particular character was above or below the average; and although those which did not differ noticeably from the average would be most numerous, yet those which were very considerably above or below the average might certainly be reckoned (as I stated) at one quarter of the whole, so that nature has to select for her purposes from this enormous number of favorable or unfavorable individuals.
>
> As it is certain that, of all living creatures which are born every year, by far the *larger portion* die without leaving offspring—i.e., in infancy or in early youth—it necessarily follows that those which are in some way inferior or imperfect will, on the average, be those from which the next generation is not produced. Those that survive and do leave offspring will therefore be, on the whole, better adapted to their environment, and as almost every conceivable character does vary in this way, there is an overwhelming amount



June 27th. 1913

Old Orchard,
Broadstone,
Dorset.

Dr. L. Williams

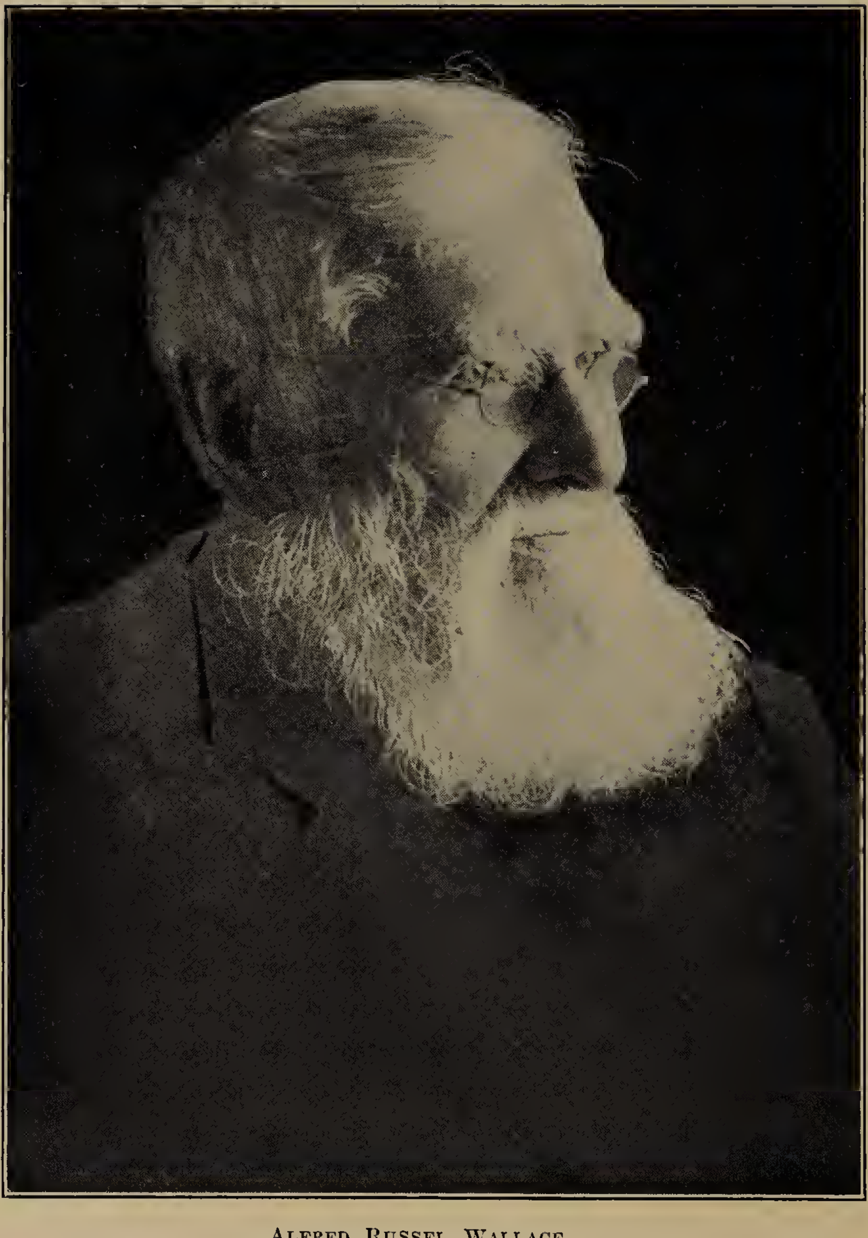
Dr. Sir

I hope the enclosed statement will sufficiently answer your question. The main points want stating & restating again & again to impress the ordinary ignorant objector.

Yours very truly

Alfred R. Wallace

Facsimile of Letter from Dr. Wallace Which Accompanied His Statement Given on Page 238.



ALFRED RUSSEL WALLACE.

of material to carry on a continuous improvement as regards any beneficial change.

It is therefore absolutely inconceivable, taking the facts of variation to be as they have been proved to be, that the course of evolution could ever have depended on a few pairs of individuals only.

The large numbers of measurements and of observations which have been made demonstrate that in respect of variation there is no essential difference between man and all other animals. It is also certain that an enormous majority of animals multiply much more rapidly than does man.

Nature has everywhere in all parts of the world an overwhelming number of favorable variations to select from and it is this immense surplusage of material, and not the chance variation of a few individuals, which gives to her operations such a much greater certainty, universality and power of minute adjustment than those of men.

It is therefore absolutely certain that each successive ancestral form which led to the evolution of man did exist in such vast numbers and did offer such an amount of variation as to give it in each case the superiority which was necessary to the successful operation of natural selection.

It is the vast scale on which nature works that is always forgotten by objectors, and it is this that demonstrates the complete fallacy of both the Mutationists and the Mendelians. They alike deal only with comparatively very rare variations, the former with what are called *sports*, the latter with *abnormalities*, which usually occur among domesticated animals or cultivated plants and therefore cannot possibly have been the agency by which the vast scheme of evolution has been carried on for millions of ages through the whole of the seas and lands of our globe. That agency is the *universal* and *conspicuous variability* of every part and organ of all living things.

ALFRED R. WALLACE.

* * *

"That is probably the clearest and most emphatic statement that Dr. Wallace has ever made on this great subject. It seems to dispose very effectually of the theory of a single pair of ancestors for the human family. But if that statement were permitted to stand alone it would entirely mislead most people reading it as to Dr. Wallace's views on the part natural selection is to play in the further evolution of humanity. As I have said, the dominance of mind introduced a new and revolutionary factor into the problem. Hear what Dr. Wallace says on this point in his recent book on *Social Evolution and Moral Progress.* After saying that the whole animal world was 'preserved in harmony with its slowly changing environment by modification of its own organs or faculties,' he proceeds with the following fine passage:

" 'We see, then, that with the advent of man there had come into existence a being in whom that subtle force we term *Mind* became of far more importance than mere bodily structure. Though with a naked and unprotected body, *this* gave him clothing against the varied inclemencies of the seasons. Though unable to compete with the deer in swiftness or with the wild bull in strength, *this* gave him weapons with which to capture or overcome both. Though less capable than most other animals of living on the herbs and the fruits that unaided Nature supplies, this wonderful faculty taught him to govern and direct Nature to his own benefit, and compelled her to produce food for him almost where and when he pleased.' Thus arose this being who brought a new order of things into life.

* * *

"I think that statement by Dr. Wallace will come as a great surprise to the majority of my hearers who have probably not regarded man as in any way set apart by the great teachers of the doctrine of evolution from the action of the laws which govern the rest of the animal world. And yet Wallace adds that this statement, as originally made, was submitted to both Darwin and Spencer and by both approved. But Dr. Wallace has now carried this teaching much farther. Near the close of the volume from which I have previously quoted he says: 'When men and women are, for the first time in the course of civilization, alike free to follow their best impulses, when idleness and vicious or hurtful luxury on the one hand, oppressive labor and the dread of starvation on the other, are alike unknown; when all receive the best and broadest education that the state of civilization and knowledge will admit; when the standard of public opinion is set by the wisest and best among us and that standard is systematically inculcated on the young; then shall we find that a system of *truly natural* selection will come spontaneously into action which will steadily tend to eliminate the lower, the less developed, or in any way defective types of men and will thus continuously raise the physical, moral and intellectual standard of the race.' Dr. Wallace holds the opinion, you see, that man himself is to introduce and control by power of mind the very factor which will aid his further evolution. Evolution is now to become predetermined by man. There are, on every side, unmistakable indications that the great mass of humanity is determined that these things shall be. Consider for a moment the meaning of it. It means, as the writer of a very notable book has put it, that the 'struggle for human expression,' with all the immeasurable range of achievement implied in that phrase, is taking the place of the old struggle for bodily existence. And that phrase, 'the struggle for human expression,' does not mean specially the building of more and bigger houses, stores and steamships, longer railroads and swifter means of transit; these things may possibly be involved in such an expression, but what it definitely and specifically means is the surging-up, under the stimulus of a great and growing power of determination, that all of those human qualities which do distinguish man from the brute shall have free play in an environment in which no individual soul shall be fettered by unjust conditions of life. . . .

* * *

"Henceforth the evolution of man is largely under human control. Whatever power presided over his destiny during the long ages of preparation for the self-conscious phase of his existence, when man entered that arena he assumed the responsibility for his future course. From that time forward his destiny was in his own hands. The long, long struggle had really always been the struggle of mind for the supremacy over matter, the effort to bring the finer, eternal harmonies of the spirit out of the temporary discords of the grosser substance. All evolution, so far from being the result of conflict and destruction, is ultimately the outcome of increasing harmony in activity. Is not that the golden thread of the increasing purpose that runs through all creation? 'A teleological impulse working through mechanical conditions,' as Hobhouse has recently expressed it. . . .

* * *

"The conflict between individuals, species and races is only one aspect, and that perhaps not the more important one, of a struggle that is universal, cosmical. The effect of natural selection acting on the result of this universal struggle is always to preserve those organisms having the most harmonious balance of parts. . . . The triumph of mind always means the decrease of discord and the increase of harmony. When natural selection has improved a species up to a certain level a new synthesis of harmony becomes possible. That new synthesis may appear suddenly—perhaps always has so appeared. That is the doctrine or theory of mutation. But every species contains within its own ranks individuals in every grade of evolution comprised between the levels of a lower and next higher synthesis. This causes the appearance that evolution proceeds by the almost infinitesimal advances resulting from natural selection alone. And that, if I may venture to criticize so great a man as Dr. Wallace, is the origin of his error that continuous variation and natural selection alone are sufficient to explain the origin of species.

"The *essential* struggle between individuals or species ended with the appearance of man. That is the reason why no new species has appeared since his advent. The great struggle between mind and matter had at last resulted in the production of an organism capable of subduing and utilizing all the powers of nature. Mind had emerged triumphant from the conflict of a hundred million years. Henceforth the only essential struggle was that of the individual to produce harmony in his own nature, and that struggle summarizes and exhibits in an abbreviated and condensed form the whole long conflict that has been waged from the slime of the old Cambrian sea to man, just as the material human embryo in its evolution summarizes the development of all preceding life.

"We repeat, then, that the fundamental principle of evolution is harmonious activity, and complete harmonious activity in an organism is not possible except by the complete dominance of mind. And that will ultimately appear. Humanity will prove itself equal to the task of destroying individual and race conflict, and hand in hand with this great accomplishment will proceed the equally noble work of improving the quality of the individual. The 'increasing purpose' will not be balked, the great destiny of man will be fulfilled."

PART FIVE

PAINTING
LITERARY MISCELLANY

CHAPTER XXVI

PAINTING

ITALY exercised upon Dr. Williams the attraction which beauty, natural and man-made, always exerts over the artist. In February 1905 he went there for relaxation and stopped first in Rome to revisit some of the old churches. He had a severe cold, but after it had passed he thought no more about it and went on southward. While sketching in the vicinity of Naples, he was taken seriously ill with malarial fever and was confined to bed for ten weeks.

His room was so situated that while lying in bed he could look across the bay toward Vesuvius, which, when he was taken ill, had been in mild eruption for several weeks. Each day it threw up rocks; each night it glowed brilliantly against the dark sky. Two or three rivers of lava ran down the side toward Dr. Williams and showed a dark, smoky pall in the daytime and red at night.

During the long period after Dr. Williams began to mend and before he could be up and about, he studied the mountain and its manifestations attentively. One day, when he was sitting with some friends at dinner, they heard a deep rumbling sound which the others thought to be thunder, but Dr. Williams, from his study of the mountain, was led to say, "I guess that is something more profound than thunder."

About half past one the next morning he was startled from sleep, probably by some sound from the mountain, and waked just in time to see a column of fire at least a thousand feet high burst from the crater, thrust straight upward and spread out wide at the top. When daylight came, the ashes, which seemed like lava sand, were so deep that many buildings had been crushed by them. Over the beautiful Bay of Naples hung a great pall of black smoke and through it came, one after another, scores of fishing smacks, each carrying from seventy-five to a hundred people who had fled down the mountainside and had lost all their possessions except the clothes they wore.

So great was the danger of the descent of poisonous gases that Dr. Williams immediately procured a ticket for Rome. His train left in the late afternoon. As it drew out of the city, he got a view of the pall of smoke hanging over Naples. The rays of the setting sun shone in under the smoke and lighted up everything with the most weird and unearthly light he had ever seen.

* * *

From early boyhood days painting and drawing had a great fascination for Dr. Williams. As a child on the old farm, he had made colors by squeezing out beet juice for red, steeping oak bark for brown and using such other materials as he could find to produce slightly varying tints. With this crude outfit he often attempted to copy the few colored prints which hung on the walls of the humble home. Later, from time to time as opportunity offered, he attempted to arrange pigments on canvas to represent scenes in nature. He was to wait many years for the opportunity to develop his talents.

Following the illness at Naples he was advised by his physician to take a long rest and not return to practice for at least two years. When he was thus forcibly relieved of his ordinary occupations, the old inclination for drawing and painting came to the fore and he could now give it serious attention. He already had many friends among artists and had often accompanied them on sketching expeditions, so that he was fairly familiar with the fundamentals of procedure in modern painting. He immediately placed himself under the instruction of one of the most competent art teachers and went to work in earnest.

Within two years from the time he began serious work several pictures had been accepted by leading art exhibitions in London and a Bond Street art dealer had offered to give an exhibition of his work. He received numerous offers for his paintings, but he had not taken up painting as a source of income and he did not care to dispose of his work. However, when a collector offered him a thousand dollars for a

MONT BLANC.

From a sketch by Dr. Williams.

painting of 12x16 inches, the temptation was too strong to be resisted. This picture is the only one which he ever sold. On the walls of his Concord Haven home in Maine hang most of the best of his pictures. The reproduction of a sketch of Mont Blanc, painted from the window of the hotel at Sallanches at a single sitting, well represents the style and character of his work. This sketch was made especially to show the great glaciers of Mont Blanc and the manner in which they are formed. It was used to illustrate certain characteristics of the Ice Age as described in his lecture on *Prehistoric Man.*[1]

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[1] This lecture, in condensed form, begins on page 228.

CHAPTER XXVII

LITERARY MISCELLANY

"THE HOME AND HAUNTS OF SHAKESPEARE"

DR. WILLIAMS spent the summer holidays of his first years in England in the vicinity of Stratford-on-Avon. Like thousands of other people, he was first attracted thither by Shakespeare's verse. Soon the restful beauty of the Warwickshire scenery made a singularly winning appeal. He found there the repose that was made necessary by his own physical condition and the demands of the London practice.

Before he had been there long, he began to see that although rural England changes slowly it was changing and at an accelerating pace. These changes threatened to destroy the conditions and atmosphere from which Shakespeare had drawn the inspiration for some of his finest works.

When Dr. Williams became able to visualize what these conditions must have been, he began to feel a sense of personal loss as he realized what the changes were destroying, and he knew that others would feel that loss in increasing degree as time passed. He resolved to perpetuate those conditions on paper for the benefit of Shakespeare lovers the world over, employing for that purpose his pen for writing, his camera for photographing and the services of artists to make paintings. In this work he spent the summer holidays of four years.

He took several hundred photographs, for some of which painstaking preparations were necessary in order to produce the conditions as they must have been when Shakespeare wrote. The illustration *When We Were Boys* is one such picture. He enlisted the services of several artists of note, who made paintings of the sort he desired at the localities he selected.

"When We Were Boys"

From Dr. Williams's book, *The Home and Haunts of Shakespeare.*

Ann Hathaway's Cottage

From Dr. Williams's book, *The Home and Haunts of Shakespeare.*

After the vicissitudes which seemed to be inseparable from the publication of books the work was brought out by Charles Scribner's Sons in 1892 in several editions, and more than 12,000 copies were sold. The book contained fifteen full-page reproductions of Warwickshire scenery in colors, forty-five full-page photogravure plates and more than one hundred and fifty other illustrations from special photographs which Dr. Williams took.

The edition, which sold at $37.50 per volume, was an extremely fine piece of book-making. Specially bound copies were presented to Queen Victoria, and later to Queen Alexandra, and to the present King of England at the time of his marriage. Letters of grateful acknowledgment were received in response.

* * *

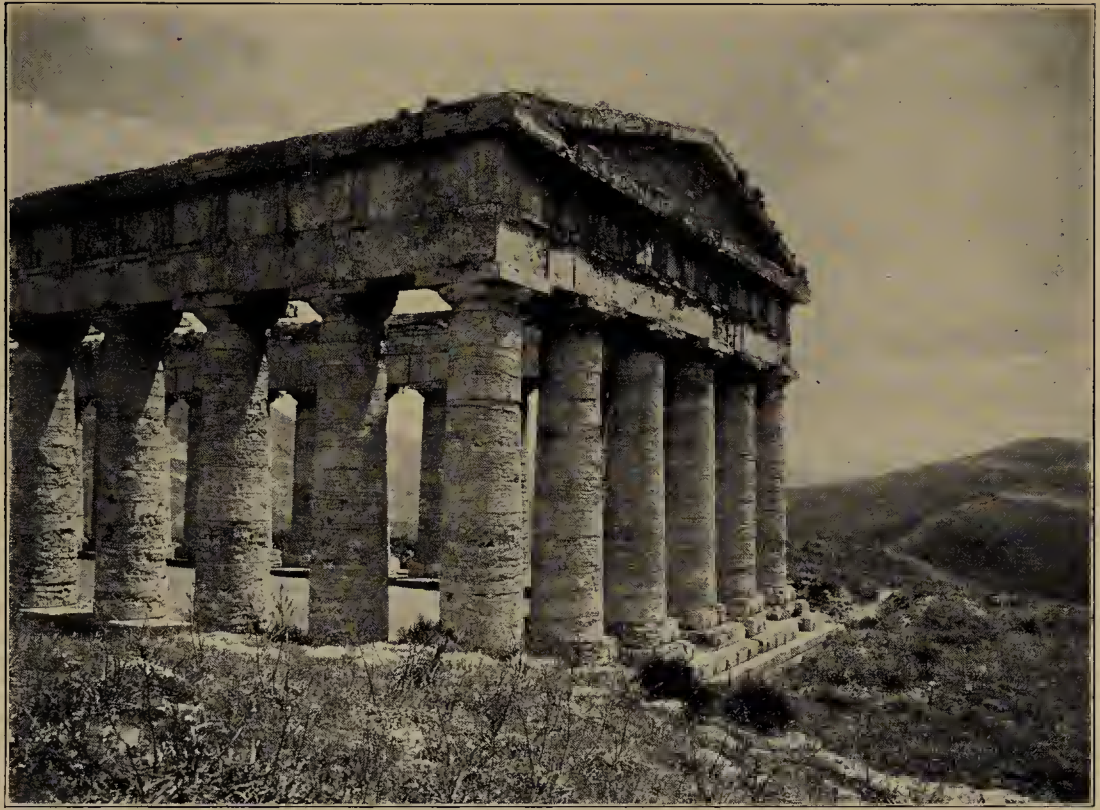
Dr. Williams was able to make a valuable contribution to the critical study of one of Shakespeare's plays. Nearly all of the great Shakespeare critics have broken their teeth over certain aspects of the *Merry Wives of Windsor.* Tradition says that Queen Elizabeth was so pleased with the character of Falstaff when she first saw it in *Henry IV* that she requested Shakespeare to write another play giving greater prominence to this character. It was in response to this request that he wrote the *Merry Wives of Windsor,* which was first performed at Windsor Castle.

In the edition of this play as it was performed at Windsor Castle there are some humorous lines about Sir Thomas Lucy of Charlecote, who, it will be remembered, is said to have been responsible for Shakespeare's sudden departure from Stratford-on-Avon because of the deer-poaching episode in Sir Thomas's park. Sometime after the first performance Shakespeare rewrote the play and made very substantial changes in that part of the opening which refers to Sir Thomas Lucy. These rather remarkable changes have greatly puzzled the critics. It appeared to Dr. Williams that the stories of a few apparently unrelated but well-known events, when properly put together, cleared up the mystery.

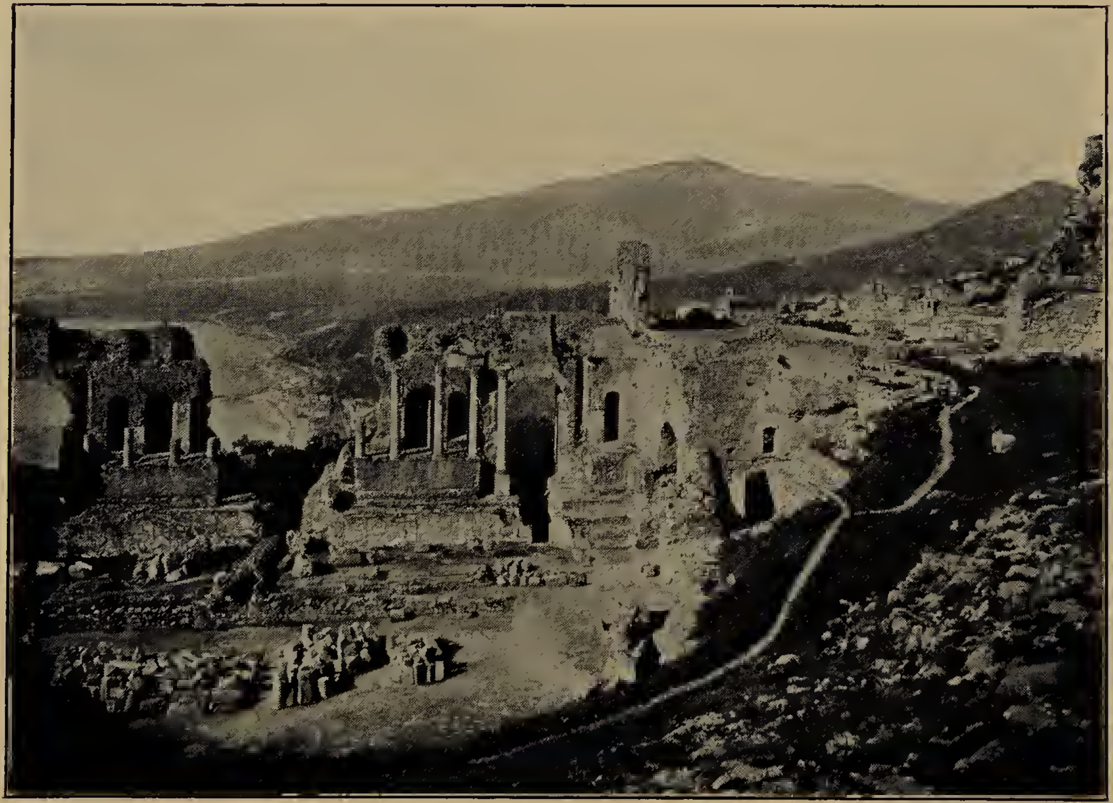
It seems that soon after the first draft of the play had been performed at Windsor Castle Shakespeare had become prosperous and desired a coat of arms for his father, then mayor of Stratford-on-Avon, who, as a man of some importance there, was as much entitled to this honor as many others who had received it. It is known that Shakespeare's request for this coat of arms was opposed by a member of Parliament. Only one member of Parliament had the slightest interest in Shakespeare's father and the proposed coat of arms, and that man was Sir Thomas Lucy, whose enmity William Shakespeare had already incurred. This enmity probably did not grow out of the deer-poaching episode, which was simply a boyish freak and not likely to have seriously disturbed Sir Thomas. But John Shakespeare was very liberal in religious matters, and it is said that he had Catholic proclivities, though he was probably not of that Church. It is known that Sir Thomas was a Puritan and bitterly opposed to Catholicism. Furthermore, if John Shakespeare got his coat of arms, he would be a social rival of Sir Thomas at Stratford-on-Avon. The danger of a possible social rivalry from one who had come up from so lowly an estate and the religious antagonism seemed to supply a sufficient motive for Sir Thomas to oppose the granting of a coat of arms to John Shakespeare. Sir Thomas was a very influential man at court. The opposition was successful and the coat of arms was not granted at that time. Shakespeare was undoubtedly aware to whom he owed the defeat of his application. He rewrote the *Merry Wives of Windsor* and, taking advantage of certain peculiarities of Warwickshire speech which gave to the word "louse" the sound of "loose," and also of the fact that the Lucy coat of arms bore the symbol of three fish called "luce," he held the coat of the Lucy family up to the ridicule of all England.

"The Land of Gray's Elegy"

Dr. Williams wrote also a most attractive book entitled *The Land of Gray's Elegy,* which was published in a holiday edition and was well received by lovers of Gray.



The Unfinished Greek Temple of Segesta, Sicily.



The Graeco-Roman Theatre at Taormina, Sicily, with Mount Etna in the Distance.

"THE LAND OF DEPARTED GODS AND OLD ROMANCE"

At the time when he undertook to awaken the dental profession to an appreciation of better forms in artificial teeth, he had been engaged for several years in the preparation of a book on Sicily to be entitled *The Land of Departed Gods and Old Romance.* For this book he had made some hundreds of photographs.

Perhaps no other land is today better suited than Sicily to attract the lover of Greek history and architecture. The colonies which the Greeks established there about 734 B.C. flourished until Syracuse nearly rivaled Athens. Finally war between these two cities broke out and some of the most stirring episodes in Greek history occurred on the island.

As a result of war between the Sicilians and the Carthaginians, the building or completion of some of the Greek temples and theatres was interrupted or stopped. Sicily is subject to frequent earthquakes, which have probably done more harm to the temples and theatres than all the invaders combined. With the exception of the Temple of Diana, the Greek temples in Sicily exceeded all others in size and beauty.

Fortunately, it is possible to reproduce here two of the photographs which Dr. Williams took for the book he planned to write.

PART SIX

PHILOSOPHICAL AND ETHICAL WRITINGS

PREFACE TO PART SIX

Leon Williams's boyhood was spent on the banks of the Kennebec. The view from the home farm was bounded in one direction by a mountain, *Old Moxie,* about thirty miles to the north. One day, as the boy sat conjuring up pictures of what might lie behind it, he asked, "Father, what is beyond that mountain?" His father knew that the boy, with his grandmother's aid, had just completed the reading of *Pilgrim's Progress* in which the expression "The Delectable Land" was used to describe the country on the other side of the mountain. Applying this newly won knowledge, the father answered, "The Delectable Land."

From the day when Leon began to study Comstock's *Philosophy* in the little schoolhouse at Solon philosophy became to him a highway upon which his mind might travel toward the Delectable Land. It has never ceased to be such to him and he is still traveling toward it.

Later Williams, as the young scientist, accepted Spencer's thought that the sciences (physics, chemistry, etc.) should seek to answer man's question "How?" as applied to the material world and that philosophy should correlate the results of all the sciences and seek to answer man's question "Why?" As man progresses in thought, the question "Why?" may become more important to him than his first question "How?" since from his answer there may spring a better perception of the inner man, the psychical, who should grow out of the material man as a flower grows out among leaves.

The author is glad to present here, as well as possible in a brief space, some examples of Dr. Williams's philosophical and ethical writings.

CHAPTER XXVIII

Dr. Williams's First Philosophic Presentation

DURING the early years of Dr. Williams's professional life materialism was rampant in the scientific and philosophical worlds. Its leaders were Haeckel in Germany and the followers of Darwin in England. According to the materialists all life, physical, intellectual and emotional, was mechanical in nature. The physical activities of assimilation, reproduction and motion, as well as the keenest thought, the strongest desire, the highest inspiration, the tenderest love and the most self-sacrificing service, were all explainable merely as the results of chemical interactions among molecules. A slight change in the chemical activities would void the thought, kill the desire, dull the inspiration, abolish the love and terminate the service. If the former chemical relations were reestablished, all the activities would reappear exactly as they were before.

Against this belief Dr. Williams took his stand. He had been working for some years with his microscope. He knew very well that certain aspects of life were chemical and mechanical. While he did not seek to minimize these, he believed that life, even on the physical plane and from the viewpoint of the scientist, was something more than mechanical and chemical. And so, at the age of twenty-nine, he contributed the article which follows to *The Dental Cosmos* for 1882.

It is interesting to note that after the lapse of more than forty years much of the best scientific thought of the world is strictly in harmony with the conception of vital force set forth in this article. This change of thought is due in large part to the efforts of Bergson, Lord Haldane and his brother, Professor Haldane, Professor Dreisch in Germany, Professor J. Arthur Thomson, Sir Oliver Lodge and others.

"LIFE AND VITALITY"

"During the past year I have noticed in the reports of the transactions of many dental and medical associations quite frequent criticism of the use of the term 'vitality.' I believe that there is reason for this criticism, because of the ambiguous manner in which the term is used and the uncertainty as to the meaning which those using it really intend to convey. But the term when intelligently used is one which cannot well be spared from our vocabulary, and it is my purpose in this paper to show that it may be used with as much scientific exactness as the term 'irritability' or 'chemical affinity.'

"There are at the present time not a few scientific teachers, men of scholarly attainments and profound thought in the line of their work, whose influence is being widely felt in the direction of their efforts to reduce biology to a problem of mechanics.

"Accepting Mr. Spencer's definition, as the best that has yet been proposed, that 'life is the continuous adjustment of internal relations to external relations,' the efforts of these disciples of the school of 'affinities' and 'oxidations' seem to be, first, to reduce the first coefficient in the problem to terms which shall also, in their ultimate rendering, be but another way of expressing the last, and thus to them, the only coefficient in the problem. They desire that the 'last analysis' shall show only 'external relations.' The method is grossly unphilosophic, and unless science ends a long way before philosophy begins, it is also grossly unscientific.

* * *

"The phenomena of life everywhere present *qualitative* as well as quantitative relations; but a long-continued habit of contemplating a problem from one point of view only produces at last an almost complete inability to grasp an intricate problem in all its relations. Even in the use of such terms as chemical affinity and gravitation, which are supposed to express with mathematical precision relations of matter which may be demonstrated to sense, there enters the coefficient of quality as not the less important of the two.

"Properties should never be mistaken for entities. Chemical affinity or gravitation does not draw atoms or aggregations of atoms together. They are only abstract expressions by which we indicate something of the *qualitative* relationships of matter. Herein lies the error of the materialist; he is constantly mistaking the *method* by which matter under certain conditions acts for the *cause* of the action; and he persistently refuses to recognize the fact that man's consciousness is related to the phenomena of life as exhibited in matter by a very narrow scale of three degrees—touch, sound, and sight—the other senses being only modifications of the first. A low degree of motion we call the sense of touch; that motion increased, our consciousness recognizes a new quality which it calls sound; still further augmented, it speaks a second time through the sense of touch as heat; a more intense action reaches consciousness as light, and then, as the brain is unable to report more than 800 billions of vibrations in a second, the activities of matter pass beyond the scope of our consciousness surrounded by a halo of intense violet light. Above and below this narrow scale roll the infinite tides of life. Inasmuch, then, as man knows so little of the purely material aspects of life, it behooves him to be exceedingly careful in making statements which imply that he has taken into the account all of the qualifying conditions.

* * *

"Now let us briefly examine some of the phenomena of life as revealed to us through this narrow scale or window of our consciousness. Neither idealism nor materialism is alone a sufficient guide in interpreting life. In endeavoring to understand a phenomenon we should consider it in the light of a knowledge of every ascertainable condition.

"Life is both objective and subjective, and its conditions may sometimes be approached only from one side. If we are approaching from the objective side, then idealism, both in methods and in terms, should be rigidly excluded. On the other hand, if we are approaching the problem from the subjective side, then materialistic methods must be abandoned for the time.

"From an objective point of view an organism may be said to be a mechanism the relations of which may be expressed by a mechanical interpretation. We recognize the presence of phenomena in organisms which belong to physical and chemical agencies. But an organism is something more than a machine. As I remarked in my reply to Prof. Mayr, in the March number of the *New England Journal of Dentistry,* 'Any theory of the origin of any form of organic existence which fails to recognize the subjective condition of life must end in darkness and confusion.' And I may now add that any attempt to explain the perpetually recurring phenomena of organic existence which ignores the subjective factor in the problem must also end in darkness and confusion. It is always well to express first all that is known or can be learned of the physical or chemical relationships of organisms in physical and chemical terms. But every such relationship or change so expressed is simply a change of position determined by some preceding change. Now, movement implies force, and the *nature of the forces* in operation must also be taken into the account. While it is true, as Prof. Mayr has remarked, that the progress of biology has forced those who make the word 'vitality' a sort of makeshift, or a screen behind which to hide their ignorance to 'pitch their tents a little further west'; or in other words, while such progress has shown more and more the machinelike adjustment of the several parts of an organism, and the possibility of explaining by physico-chemical changes many things concerning the phenomena of organic life which were formerly attributed to the agency of some superphysical, mysterious principle, it has *also shown more and more* the intervention of conditions which it is not possible to explain from an objective point of view.

"When the term 'vitality' or 'vital force' is made to stand for some mysterious principle, some unknown cause dissociated from all known conditions, then it becomes a negation; it means nothing, or it may mean anything. Vital force as an extra-organic agent has no existence.

"If the conditions governing chemical changes in an organism were identical with those under which such changes occur outside of an organism, then there would be no use for such terms as 'vitality' and 'vital force.' But every careful observer knows that there is something in an organism which sets at defiance and sometimes wholly frustrates what we call chemical affinities. The instances cited by Lewes are to the point. He says: 'Even the ordinary laws of diffusion are not always followed in the organism. The amoeba, though semi-fluid, resists diffusion when alive; but when it dies it swells and bursts by osmosis. The exchange of gases does not take place in the tissues precisely as in our retorts. The living muscle respires; that is, takes up oxygen and gives out carbonic acid, not on the principle of simple diffusion, but by two separable physiological processes. The carbonic acid may be given out even when there is no oxygen whatever present, and its place may then be supplied by hydrogen; and this physiological process is so different from the physical process which goes on in the dead muscle that it has been proved by Ranke to go on when the temperature is so low that all putrefaction is arrested.'

* * *

"The whole period of the cycle of existence of a living organism is that of continuous resistance to the laws of diffusion and chemical affinity as ordinarily manifested. What I have once before said upon this subject is so to the point here that I may be pardoned for again quoting from a former article.

" 'The pages of this magazine might be filled in describing the differences which exist between any observed chemical changes and the phenomena exhibited by the simplest particle of living matter. All scientific investigation, instead of narrowing the gulf which separates living from non-living matter, is constantly widening it. The power of chemical change is molecular. The force which determines chemical action or reaction resides in each individual molecule, and the conditions necessary for the exhibition of these forces are, to some extent, under human control. But no chemist has ever "breathed the breath of life" into a single particle of living matter. None ever will.'

* * *

"Now, while I believe there are more things in heaven and earth than are taught in the materialistic philosophy, yet I do not wish to be understood as urging that my reasoning necessarily implies the existence of *any* superphysical or extra-organic principle. On the contrary, I desire to demonstrate, as I stated at the commencement of this article, that it is possible to prove, on purely scientific grounds, that the changes which take place in a living organism are so different from those which occur outside of it as to necessitate the existence of widely different conditions. And *this difference in condition is just what we propose to designate by the term 'vitality';* or, speaking more exactly, *vitality may be said to be the ensemble of all the cooperant conditions under which the changes in matter occur in a living organism.*

"Is there any lack of scientific exactness in this use of the term? We need some abstract expression for designating those complex conditions necessary to the manifestation of organic phenomena, and I can think of no more appropriate term for this purpose than that of vitality. There is a vast difference between organic and *organized* forms, and vitality stands as the representative symbol of that special *state* which we call *organization.* This use of the term 'vitality,' while it keeps persistently in view the radical difference between an organization and an organic compound, is at the same time free from all objections which have been brought against its use when interpreted as a principle or entity. When thinking of the phenomena manifested in an organism we may very properly, in our analytical conception, take into account the physical and chemical agencies which form essential components of the act; but at the same time we must recognize that these agencies fall so far short of expressing all that we witness when the molecular equilibrium of an organism is disturbed that we use the term 'vitality' for the broader comprehension which it symbolizes.

"Neither is there any danger of confounding the meaning of this term with that of life, for by life we mean the special mode of existence of an organism. Vitality may mean the same whether applied to mollusk or man. It stands always as the symbol of the cooperant conditions of the organism which exist at any moment; but between the life or *manifestation* of vitality as exhibited in mollusk and man there is a wide difference. *Life* may be said to be a dynamical expression of the manifestation of an organism, while vitality is the *statical* expression. When we speak of chemical or physical forces or agencies, we speak analytically. When we speak of vitality and life, we imply synthesis. The use of the latter is quite as important as the former; and synthesis is after all the last and only true explanation. I do not wish to undervalue the aid derived from analysis, but I recognize that it is at best but a logical artifice, a preparation for that more comprehensive conception which is synthetic. I have, in a previous article, expressed my opinion concerning the undue importance with which analysis has been regarded and the tendency which this too implicit reliance upon its methods has had in leading to a lack of discrimination of the profound difference between organisms and machines."

CHAPTER XXIX

A Plea for a Broader Scientific Foundation

THE manifestly scientific character of the research work described in the paper presented by Dr. Williams before the Odontological Society of New York in 1897 entitled *A Contribution to the Study of Pathology of Enamel* and the inescapable conclusions which resulted from that work not only made a profound impression on certain men prominent in the profession but inspired the hope that work of that character might be continued, if not by Dr. Williams, then by others, perhaps with his advice and assistance.

Accordingly, on the eve of Dr. Williams's departure for Europe, there was arranged a dinner for him at the Lotos Club, New York, to which were invited a number who were in sympathy with the desire to foster scientific research. As the dinner was drawing to a close, the late Dr. Northrup, who presided, rose and said something like this:

"Dr. Williams, you have given us a wonderful intellectual treat and strengthened in us the desire that scientific research should be encouraged among us. Have you any suggestions as to what lines of study should be undertaken and by what methods the work should be done?"

In reply Dr. Williams stated that the line of investigation as to the part microorganisms play in caries had been definitely exhausted and that the next step would have to be a study of all the environmental conditions of the teeth. He suggested some lines of study and certain ways of procedure and said that he would, if desired, give the matter further thought and gladly aid with suggestions and advice.

This reply was received with satisfaction. Moved by the sincerity and apparent enthusiasm of those present, Mr. Lewis, then President of the S. S. White Dental Manufacturing Company, offered, on behalf of his Company, to donate the sum of two thousand dollars for the furtherance of the investigations, if those present or interested would donate a similar amount. At this evidence of practical liberality the enthusiasm ran higher than before and it seemed as if something worth while might be started. The matters of subjects, workers, methods, etc., were to be given immediate consideration. Dr. Williams sailed for London in high hope that he would soon hear that earnest workers were being aided by the fund which was to be raised. Month after month went by and nothing came of this grand plan. Nothing ever did come of it—it blew itself out in talk! And it remained for a man outside of dentistry, Professor W. J. Gies, to take up the very line of study which Dr. Williams had suggested.

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After Dr. Williams returned to London there gradually grew up in his mind the conviction that the theory and practice of dentistry rested upon a very small foundation of really scientific work; that when such work was done by some member of the profession at his own expense in time and money and was presented to the profession, it was usually received in silence or with antagonism by those who should have been the first to welcome it; and that men of influence in the profession, who could not originate such work, who did not understand it and could not reproduce it, paraded frequently and loudly empirical beliefs which could not be held by anyone who had even a slight knowledge of the subjects.

He felt that this attitude on the part of men whom other dentists looked upon as leaders not only was a brake on the wheel of progress but menaced the only means by which the profession could hope to make progress, i.e., self-sacrificing effort on the part not only of those who had a broad view for dentistry but of those also who were able to do research work. The longer he thought about these conditions, the more it seemed worth while for some one to strip this cloak of assumed knowledge and authority from those who were not entitled to wear it and incline the minds of the profession as a whole to a more kindly reception of the really fine work which had been done for it. So, in January 1899 he came again to America and presented before the Odontological Society of New York an address from which summaries and extracts follow.

"WHICH SHALL IT BE, THE EMPIRICAL OR THE SCIENTIFIC METHOD?"[1]

"What is science, and what is it to be scientific in spirit? The simplest and most comprehensive definition of the term is 'a systematized arrangement of natural facts.' Any man who is engaged in observing the facts of nature and arranging a record of those facts with special reference to their related significance is, just to the extent of his labors, a scientific man." Dr. Williams gave interesting illustrations of the application of these principles in the lives of Galileo, Darwin and Edison.

In order to make his contrast between those who did original work and those who merely read or heard about it and then talked, he reminded his hearers that all the great teachers and investigators discourage the use of books as primary sources of knowledge. He referred to Edison's statement that it has taken him about as long to unlearn the errors he imbibed from books as to accumulate his own store of facts, instanced the fact that Agassiz would have no books for his pupils and quoted from Huxley's criticism of the book-made man, as follows: "Not only is he devoid of all apprehension of scientific conception . . . but, worse still, he has no conception what it is to come into contact with nature or to lay his mind alongside a physical fact and try to conquer it in the way our great naval hero told his captain to master their enemies."

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He continued: "I suppose there is no error in the world which has not some fact as a foundation, and all errors consist in the exaggeration of certain facts out of all relationship to other facts which modify them, and in the forcing of conclusions which the facts do not legitimately warrant. This is the empirical method. The origin of the term, which was not originally one of reproach, dates from the Alexandrian adaptation of Greek medicine, although the Empirics claimed justification for their doctrine in the teaching of Hippocrates. Its salient feature was the rejection of the study of anatomy and a general abandonment of inquiry into the causes of things. Their famous 'tripod' of principles, or the sources from which they claimed a knowledge of medicine could alone be obtained, were clinical observation, recorded observation and judgment by analogy, methods which are certainly to be commended as far as they go. But the difficulty arose in those ancient days precisely as it does now—viz., in the interpretation, or rather the misinterpretation, of the facts observed. The whole weakness and danger of the empirical method, using the term in its original sense, lies in the ever-present tendency to force conclusions or to found deductions upon incomplete or insufficient data. A good example of this is found in the teaching that because the softening of enamel is a matter of clinical observation, *therefore* the phenomenon must be due to some *intra vitam* change in the tissue. . . .

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[1] Published in *The Dental Cosmos*, 1899.

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"The empirical method was a stepping-stone to the scientific method, and with the evolution of the latter the former should have passed away. The scientific method includes all of value that there ever was in the empirical method and adds so greatly to our power of reaching truth that there is much reason for wonder that the ancient habits of thought should find defenders and followers today. . . .

"For the fiftieth time, perhaps, during the past dozen years the old question of the vitality of enamel was again brought forward at this discussion, and the consensus of opinion was that enamel must be a vital tissue. We have statements that there is organic matter in enamel, and that this has been observed to become 'disintegrated' during typhoid. . . .

"Is there any evidence that such changes occur in human enamel? Not a single fact has ever been brought forward to show that such changes take place, and there is the strongest possible evidence against such an assumption. Where do the chemical changes occur by means of which tissues are formed and regenerated? Where are the bone molecule and the dentine molecule elaborated and constructed, or where are the initial steps taken which unvaryingly lead to the formation of bone or dentine, if not in the formative organs of these tissues? Can periosteal bone be formed when the periosteum is destroyed? Or can dentine be formed when the dentine pulp is destroyed? If these questions must be answered in the negative, on what is based the opinion that an enamel molecule may be formed, or, in other words, that the enamel may be regenerated, that either formative or retrograde molecular changes may occur after the destruction and disappearance of the enamel-forming organ? . . .

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"It is noticeable that a large part of the opposition to the new view comes from the older men in our profession. They seem to feel that a change of opinion means a nullification of the work of a lifetime. But I regard that as altogether a wrong position. The condemnation comes not in having taught error, which was really not error so long as nothing better was known, but in clinging to that error after it has been shown to be such. I commend to them this saying of Marcus Aurelius, 'If anyone can convince me of an error, I shall be very glad to change my opinion; for truth is my business and nobody was ever yet hurt by it. But he that continues in ignorance and mistake, it is he that receives the mischief.'

"We would, at least, wish to see the older men in our profession content to rest with work well done. We would gladly honor them and ask them to accept our full and cordial acknowledgment of the faithful way in which they have marched forward under great difficulties. They have made wonderful progress, although handicapped in many ways and carrying heavy burdens. But must the universe stop with their passing? Must the deluge which ends all come upon us as they go? Is it not our business also to put the hand of progress forward a little on the dial of time? Why can they not accept the situation gracefully, and frankly admit that they have not exhausted the possibilities of heaven and earth? But, whether they will do this or not, nature smiles upon them serenely and, turning the page of her great book to a new problem, calls out the younger class. . . .

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"We have thus far been dealing largely with our subject in a general way. Let us briefly consider matters a little more specifically. We are engaged in the work of saving human teeth. Our efforts are aimed at the prevention and cure of those diseases which, if allowed to run an undisturbed course, end in the destruction of the dental organs. . . ."

Dr. Williams then asked two questions:

(1) "To what extent have we made progress in preventing the diseases of the teeth?"

(2) "To what extent have we established a basis of agreement as to the best methods of treating those diseases when they occur?"

"As a profession we have made little or no progress in the prevention of decay. Now, I firmly believe it to be quite within the reach of modern scientific methods to demonstrate how dental caries may be largely prevented. Are we really sufficiently imbued with the spirit of altruism to desire this? That remains to be seen. In the meantime, what have we accomplished? The preservation of the teeth for a certain temporary period. What is the average length of that period? A few years ago a Western dentist, whose name I cannot now recall, undertook a careful estimate of the average time that tooth-stoppings arrested decay. I recollect that period was placed at five years. I have for a long time been giving close study to the rate of progress of dental caries, and I find the rate is not so rapid as has generally been supposed, because there is a primary stage which had been overlooked until my studies of decay of enamel were published. I should think the primary and secondary stages would average about five years. We see, then, that the average time which a filling will arrest decay corresponds very closely with the time that is required by the microorganisms of decay to produce a new lesion. I submit that this is not a result of which we need feel so very conceited. . . .

* * *

"But what about our tooth-tinkers—are they agreed as to the best methods of tinkering teeth? Certainly not. They do not believe in scientific work, without which it is impossible to find out how even to become the best sort of a tooth-tinker. One says that amalgam is the material *par excellence* for this work, while his neighbor exhausts the possibilities of language in heaping execrations upon that substance. . . .

"Nearly thirty years ago, when I attended my first dental convention, they discussed these questions which I have raised. They were discussed long before, and they have been discussed ever since. Once a year some of you charter transcontinental trains to attend the National convention to talk over the same old problems. You talk about them at more frequent intervals in the state and district conventions. Do you not think the time has arrived when it would be well to consider whether some small part of the many thousands of dollars spent each year on these functions might not be advantageously used for the promotion of a little scientific work which would probably settle many, perhaps all, of these questions?

* * *

"Let me call your attention specifically to some of the problems which await such scientific investigation as shall raise practice out of the present empirical methods:

(1) An inquiry into the cause and best methods of treating chemical erosion.

(2) An inquiry into the causes of the disease or diseases which attack the pericemental membrane, with best methods of treatment.

(3) An investigation which shall comprise a thorough comparative test of the germicidal power of such substances as are provided for the destruction of the microorganisms of the mouth, and the adaptation of the best of these germicides to use in dentifrices.

(4) An investigation for determining the chemical differences, if any, between human saliva and the saliva of various animals which do not suffer from dental caries, and also for determining the comparative inhibitive power of various salivas with reference to the development of microorganisms.

(5) A microscopic investigation which shall involve the preparation by well-known operators of a large number of cavities in extracted teeth, and the filling of some of these cavities by different methods of using gold, and filling others with amalgams from the formulas of Dr. Black and others, and then examining and photographing through the microscope the polished margins where metal and tooth substance meet; and afterward grinding sections of these specimens to ascertain to what extent enamel affected by the acid of caries has been removed from the margin of these cavities, especially at the cervical margin of approximal cavities.

(6) A thorough comparative test of the various oxyphosphate cements in the market. . . .

* * *

"Now, we come asking for something better than this. Surely, if it is one of the important duties of the profession to protect the *public* against quackery, it is of still greater importance to protect *itself* against useless and harmful things. We ask, therefore, that the profession shall take up and exercise its own inherent prerogative of passing judgment, not individually and without investigation, but collectively, through its chosen representatives and after the most careful and rigid scientific examination, upon all instruments, appliances, materials and remedies which are brought before it. . . .

"There is an enormous amount of energy and individual effort for progress in our ranks, but a very large part of it is wasted for lack of proper organization. Now, suppose a committee or a department were to be created in the National Dental Association, to be known as the Bureau of Original Research Work and Records[1], or by some such name, with suborganizations in every state which should report to the central organization six weeks in advance of each annual meeting; and suppose there were a thousand dentists in the United States who had sufficient interest in the progress and the general position before the world of our profession to contribute five dollars each to a fund for this organization, and another thousand who would give two dollars and fifty cents each, and five thousand more who would give one dollar each. . . .

* * *

"We have been hammering and clamoring for I know not how many years at the door of Medicine, asking, beseeching, begging for recognition as medical specialists; we give ourselves all sorts of names, oral surgeons, oral specialists, stomatologists, and what not, in the hope that we may gain a nod of recognition from the world that shall imply that we are somewhat more than what is generally conveyed by the term 'dentist'; we have done nearly everything except the right thing, the dignified, manly thing. Now, if we will go to work in real, honest earnest, we shall soon enter into our rightful and desired position without asking permission of any of the older organizations. The man who feels that he is master of the situation asks no favors of anybody. Just to the extent that our profession produces work worthy of recognition by the great scientific world, that recognition will come quickly and generously.

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[1] This vision has since been partially realized in the establishment of the International Association for Dental Research.

"I do not wish to see this chosen profession of ours content with a lower level than rightfully belongs to it. I want to see it take its place among the first, and therefore I say, 'Come, let us join hands, and let all petty jealousies and small ambitions be shamed into silence in the presence of a noble enthusiasm for real progress which shall fill each and all of us.' "

CHAPTER XXX

"THE PLACE OF SCIENCE IN THE MATERIAL, MORAL AND SPIRITUAL LIFE OF THE FUTURE"[1]

"MOST Worshipful Grand Master, Brother Psi Omegas, and that other part of my audience to whom, I am sure, my brother Psi Omegas owe the most of all that is best in their lives—greetings! I am glad to be with you today and I should be more (or less) than human if I were not deeply conscious of the honor you have conferred on me in asking me to address you this afternoon.

"Let me confess at the outset of my talk that I am an idealist and an incurable optimist, but not the sort of optimist who believes that all is well in the best of all possible worlds. On the contrary, it seems to me that very much is wrong in a world that might be a great deal better. But I am an idealist in the sense that I am profoundly convinced that human destiny is a far greater thing than the majority of people think. I believe that the possibilities of human progress are not generally realized, at any given time, except by a few. In fact, true progress is not easy to see, unless one takes the long view and sees the world as a whole. Tribes, peoples, nations rise and fall, but humanity moves ever forward toward its high goal. . . .

* * *

"Two totally different types of mind or, perhaps I should say, two great, antagonistic spiritual forces seem to have been always contending in the world. Inertia is the symbol of one, and movement that of the other; one desires to remain fixed and dreads change, the other desires to be ever advancing; one believes that truth can be fixed in formulae and creeds that will be applicable for all time, the other realizes that every new discovery modifies, to a greater or less extent, all previous knowledge and that consequently truth, to be living and active, must be in a state of constant flux. In the past the theological type of mind has largely identified itself with fixedness or acceptance of tradition, while the scientific attitude of mind has been one of questioning all propositions with a view to learning the exact facts. Intellectual bondage has been the lot of one; intellectual freedom the privilege of the other. The whole history of human progress is the record of a long struggle between intellectual serfdom, born of fear and superstition, and the more complete knowledge which casts out fear.

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[1] An address delivered before the Reunion Convention of the National Alumni Chapter and the Ohio State Chapter of the Psi Omega Fraternity, July 12, 1920, at Cedar Point, Ohio.

"To know the truth is the first step toward freedom from any sort of bondage. 'Ye shall know the truth and the truth shall make you free.' It is the broad function of science to find out the truth and to make practical application of it for the benefit of humanity. Everything which characterizes our age and sets it apart from the past—the rise of democracy, the development of the modern industrial and economic system—is due directly to science and scientific methods. Everything that appertains to human well-being, everything connoted by the terms 'progress' and 'civilization,' is the result of man's mastery over the forces of nature. And as science is the key which has unlocked the storehouse of nature's vast resources, and inasmuch as economic conditions largely constitute the foundations on which social forms rest, it is therefore true, as Mr. A. J. Balfour has said, that 'science is the great instrument of social change.' . . .

"Science has largely destroyed secrecy as to the possession of knowledge, and the spirit of science is wholly opposed to secrecy. . . .

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"From facts which we now possess we are warranted in saying that it is quite conceivable that a discovery may be made at any time which will place the living world completely in the power of the one making that discovery, should he be able to control it absolutely. It is therefore becoming a matter of vital importance to determine what principles shall govern the utilization and distribution of the results of scientific discovery in the fields of the natural resources of the earth in such a way as best to promote human progress. If any law or principle could be discovered in nature to which we might ally human conduct with the certainty that such a course would best promote the real vital interests of all concerned, we should no doubt have taken a long step toward the adoption of such a practice.

"The old saying that 'the world is all right, the trouble is with the people who are in it' has perhaps more than a modicum of truth and sound sense. And the chief trouble with the people seems to be lack of vision. Vision is the great antidote to fear, and fear is the greatest hindrance to progress. Fear is of the night, when we cannot see, but courage comes with the light of morning and the exercise of our powers of vision. Science is the great light-bringer, the great stimulator of vision. But it needs no very exhaustive study of the conditions of life at the present time to perceive that real human advancement does not always keep pace with scientific discovery. Scientific discovery is the work of a comparatively small number of individuals, but human evolution pertains to the race. There can be no great racial advance until the scientific method of working and the scientific attitude of mind have become the ruling factors in race consciousness. . . .

* * *

"The early Greeks were the first to cultivate an ardent zeal for seeing things as they are. The twilight of science may be observed in ancient Egypt and Chaldea, but the dawn broke over Greece. The Greeks were the first to establish really systematic methods of study and investigation. They were the first to attempt the organization of knowledge. Sedgewick and Tyler, in their *History of Science,* say: 'Real science became possible in Greece because human thought had achieved freedom.' That is a very significant remark, and one which is applicable to all times and countries. Science flourishes best when thought is free, where minds are not bound to stagnating creeds and traditions.

"The Greeks had fearlessness of intellect. The most important aspect of the Greek genius is expressed in the motto, 'Let us follow the argument wheresoever it leads.' 'The Greeks,' says Butcher, 'before any other people in antiquity possessed the love of knowledge for its own sake. To see things as they really are, to discover their meaning and adjust their relations, was with them an instinct and a passion.' That was the spirit, the true scientific spirit, the spirit that was destined to compel the earth and the heavens to give up their primeval secrets for human use, that broke the long aeons of nature's silence.

"From Thales to Ptolemy, from Athens to Alexandria, we have the record of the laying of the foundations of modern science and the cultivation of the scientific attitude of mind. 'Except the blind forces of nature nothing moves in this world which is not Greek in its origin,' says Sir Henry Sumner Maine. And Poincaire, one of the most accomplished scientific men of our time, thus acknowledges his indebtedness to ancient learning: 'A spirit breathed of old on Greece and gave birth to poets and thinkers. There remains in our classical education I know not what of the old Greek soul—something that makes us look ever upward. And this is more precious for the making of a man of science than the reading of many volumes of geometry.' Freeman, the historian, said, speaking of the Age of Pericles: 'To have lived but ten years in the midst of it would have been worth a hundred of modern mediocrity.' . . .

"There was a spirit of opposition to the great Greek thinkers, and that same spirit of opposition has descended to our own time. The ancient conservatives and reactionaries said it was in the nature of sacrilege to be guilty of prying into the secrets of the gods. And I have heard it said from the pulpits of today, 'God does not intend us to know these things. He conceals knowledge from us as a test of our faith.'

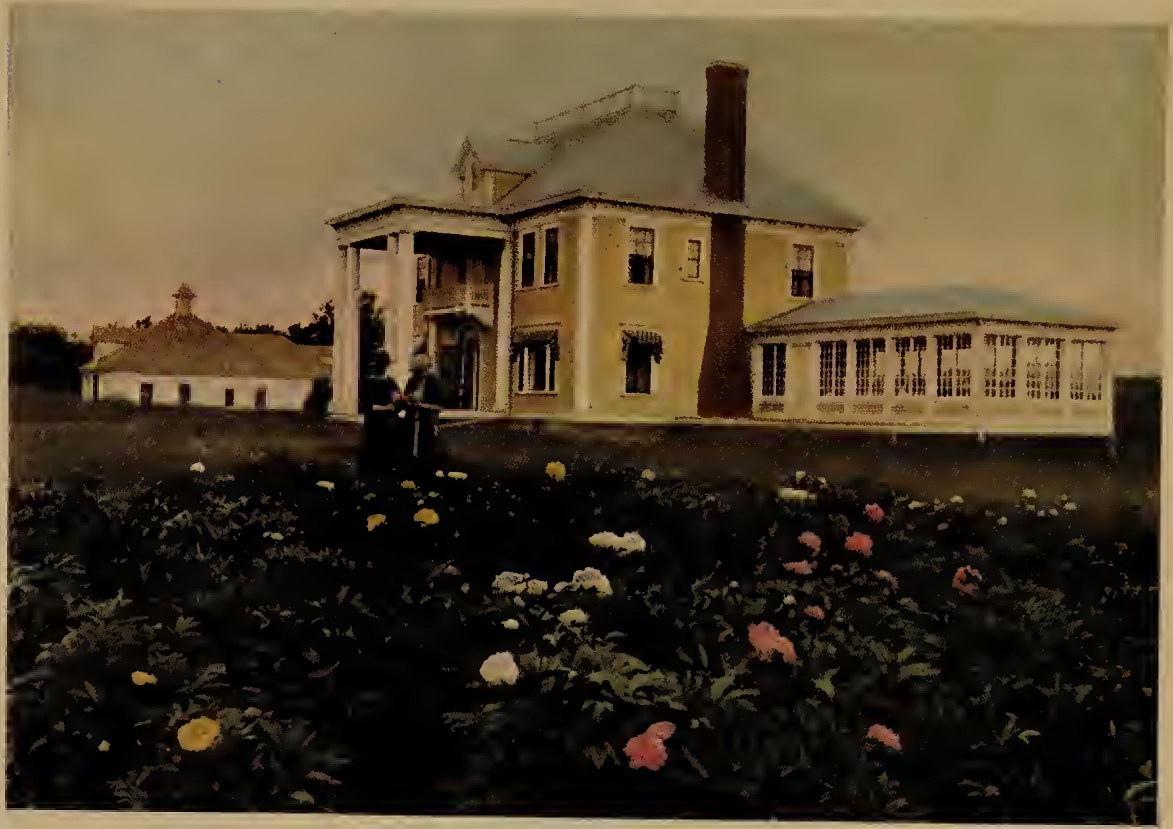
"The Greek thinkers knew that the universe could never be stripped of mystery and that the highest reverence is born not of ignorance, but of knowledge; that nature works by fixed laws and that men are not subject to the caprice of arbitrary supernatural powers. . . .

* * *

"It is one of the features of progress in human thought that extreme opinions in one direction provoke, or stimulate, extreme reaction in the opposite direction. The proof of that statement is being vividly enacted before our eyes today. For a long time the tyranny of capital ruled in the industrial world. With the organization of the workers we have an extreme reaction in the opposite direction.

"So it was when human thought began to swing away from the old theological views of man and nature. Although there should be no dogmatism in science, men who considered themselves scientific began to dogmatize. They began to exaggerate the significance and importance of certain facts and to ignore others which were of equal importance to a rational understanding of nature as a whole.

"Darwin had called attention to the 'struggle for existence' in the vegetable and animal worlds as one of the fundamental laws of life. As expressing the results of the working of this law, Spencer coined the phrase 'the survival of the fittest.' And although Darwin, Spencer and others, notably Alfred Russel Wallace, who was codiscoverer with Darwin of the law of natural selection, and John Fiske, author of *A System of Cosmic Philosophy* and one of the most accomplished scholars and profound thinkers America has produced, called attention to the evidences of cooperation and altruism as important factors in evolution, these balancing facts were largely lost sight of or ignored by the followers and supporters of the Darwinian theories. And so there gradually crystallized around these half-truth statements the doctrines of modern materialism, founded on the ideas of the struggle for existence and the survival of the fittest. Thus was the greatest scientific generalization of all time distorted, almost from the hour of its discovery, and meanings and conclusions drawn from it which are entirely unjustified by the facts. Other misrepresentations, in addition to those drawn from Darwinism, contributed to the



In 1915 Dr. Williams purchased the farm at Concord. near Solon, Maine, on which his boyhood days were passed and built this residence overlooking the Kennebec River.

From a photograph colored by Mrs. J. Leon Williams.

foundation of materialism. The inherent properties of matter and force offer, it was claimed, a complete explanation of everything in the universe, including thought and emotion. But, as we shall see, in order to make the mechanical-materialistic theory logically workable, it became necessary, in the last resort, to endow primeval matter with all the qualities of mind.

* * *

"Mercer shows the absurdity of the usual materialistic attitude of mind in the following statement: 'The mechanical theory of materialism is a product of brain processes; but brain processes are supposed by the theory to be simply molecular movements; that is to say, mere motion generates a theory to explain itself; in other words—mind does not exist and frames a theory to prove that it is non-existent.'

"The materialistic attitude of mind may be most concisely presented by two or three sayings which are often quoted.

"Lalande, the astronomer, said: 'I have swept the heavens with my telescope and I find no trace of a God anywhere.' Moleschott, the physiologist, invented the phrase, 'No phosphorus, no thought.' Haeckel said: 'Modern science has definitely ruled out the three central dogmas of metaphysics —God, Freedom and Immortality.'

"Ancient theology said that God banished man from Eden. Modern materialism retorts by saying that man has banished God from the earth. The one assertion was the effort of the childhood period of humanity to explain the origin of evil. The other is a specimen of philosophy as it is made in Germany.

"John Fiske, commenting on the two first quotations I have just read, says: 'I am inclined to think they are the two remarks most colossal in their silliness that ever appeared in print.' I agree, but the fact remains that those three quotations represent a philosophy which has profoundly influenced the thinking and conduct of a great many people during the past sixty or seventy years, so profoundly, in fact, that it required the combined efforts of more than twenty nations to overcome some of the effects of it.

* * *

"With the passing of the old, traditional, theological view of man's life in its relation to this world as a matter of secondary importance there arose a new standard of moral and material values. 'The survival of the fittest is the first law of nature,' says the materialist, and the 'fittest' are those who have the strength and the ability to get the most out of their environment. The laws of the conservation of energy and the indestructibility of matter make it at least highly probable that this material life in a material world is the only life we shall ever know. 'Is it not, then, the part of wisdom,' says the materialist, 'to make the most of the only world we know anything about?'

"Now, 'making the most of this world' has meant, for the great majority, getting everything you can lay your hands on within the limits of the law, and also by virtue of your shrewdness in evading the law, and holding all you can get. That is a bald statement of the materialistic outlook on life, but it can be supported by a thousand lines of evidence. How does this belief work out in its application to the life of the world? . . .

" 'Life is a great game,' says the materialistic Ego, 'the victories and spoils of which belong to those who are physically the strongest and mentally the shrewdest.' All the nations of the earth were more or less poisoned by this destructive belief, but only one had the brutal consistency to carry that belief into all its logical conclusions and effects. It said, openly and unashamed, 'If we are stronger than the other nations we have the right to take from them whatever we want and the success of our strength will prove our superiority and our right to dictate how the world shall live.'

* * *

"Now, if the doctrine of materialism has any foundation or justification in the facts of science and the laws of nature, then the German policy as well as that of all other peoples and individuals who practice the utilization of scientific discovery and the manipulation of conditions which they are able to control for their own benefit, and against the best interests of others, is one of the most logical consistency.

"We have, therefore, to make a critical examination of the foundation of this belief before we can express an intelligent opinion as to the part which science is to play in the life of the future. For we are what we believe, and 'no nation,' says the author of *Heroes and Hero Worship,* 'has been great that did not greatly believe.'

"When the foundations of materialism were laid, the atom was believed to be the ultimate form of matter, and matter and energy were believed to be uncreated and eternal. 'An atom of hydrogen,' says the author of *The Philosophy of Chemistry,* 'will ever remain a hydrogen atom . . . and the necessary consequence of this is that the indestructible atom cannot be created.' Again, this from Ludwig Buchner: 'But, as we have said, no further proof is needed to demonstrate that matter is indestructible; and that it cannot therefore be created. How can that be created which cannot be annihilated? Matter must have been eternal, is eternal, and shall be eternal.' All movements in matter and all forms of life, according to materialism, are due to the action, reaction and interaction of atoms and molecules. There is no directive agency; there is no purpose in anything; there is no discoverable reason why there ever should have been a universe—things just happened, that is all. The universe is the great perpetual-motion machine and chance is god over all.

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"That there is no trace of overemphasis or exaggeration in my statements is shown in the following passage from *Modern Science and Materialism* by Hugh Elliott. Mr. Elliott says, 'There is nowhere any goal or purpose to which things are directed; there is nowhere any spiritual agency to affect the blind interplay of natural forces.' There are no moral ends in the universe, or, as another eminent teacher puts it: 'The cosmic processes have no sort of relation to moral ends.' For the materialist there is nothing but an endless multitude and round of phenomena in the stupendous and orderly evolution of life. Man is 'a soulless machine in a dead world.'

"It is perfectly true that all movements in matter can be described in terms of mechanics and represented by mathematical formulae[1], but all that is mere narrative, description of movement, and tells us nothing of why movement occurs in *certain ways,* or of origins. It has nothing to do with ultimate realities. Darwin recognized this when he said, 'I have nothing to do with origins,' and forthwith ascribed the first appearance of life to a creator who, presumably, after the first fiat act, stood aside and left the machinery of materialism to accomplish the rest, left the machine that did not create itself to run itself. Two vitally fundamental things lie entirely outside of the mechanistic-materialistic theory of life. Beyond all movements of suns and worlds and controlling those movements is *gravity,* and beyond the movements of atoms and molecules and controlling those movements is *polarity.* What is gravity, and what is polarity or chemical affinity?

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"Keeping in mind the fact which I have pointed out, that the materialistic theory of life is based squarely on the belief in the uncreated, unchanging and eternal atom, we now see that of all that vast, elaborately constructed edifice there is not left one stone upon another. It lies prone in the dust, a heap of ruins; and *science destroyed it.* We know now that the atom is subject to evolution like everything else in the universe. This great discovery rounds out and completes the doctrine of evolution. It gives the last needed link in the chain of unity which binds all creation into one grand whole.

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[1] *The Mystery of Space* by Professor R. T. Browne, page 128.

"The atom is born, passes through changes and dies. With the acquisition of this knowledge there passed the ancient and modern doctrine of materialism and the significance of its passing is beyond that of any scientific event in the history of intellectual development, because materialism blocked the way for the higher evolution of man.

"With the discoveries of Gustav Le Bon, the Curies, Laborde and Crookes, the atom was *de*throned as the ultimate form of matter and *en*throned as the reservoir of undreamt-of energy and revealing in its wonderful organization some of the most profound secrets of the universe. 'Notwithstanding its wonderful minuteness,' says Le Bon, 'the atom perhaps contains all the secrets of the infinite greatness.' And, most revolutionary of all the facts revealed by the discovery of the nature and structure of the atom, is the demonstration, as an accomplished fact, of the complete destructibility of matter by the dissociation of the atom.

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"The different elementary forms of matter are now known to be organized systems of negative electrical corpuscles, revolving with almost inconceivable rapidity about a nucleus of positively charged electrons. Each atom may be thought of as a miniature solar system. The number of electrical corpuscles determines the atomic form, determines what the substance is.

"All radioactive bodies, and according to Le Bon that means all matter, emit three kinds of radiation distinguished by three Greek letters, Alpha, Beta, Gamma. Disregarding, for the moment, the first and last, let us fix our attention on the Beta emanations or electrons. They have a velocity approaching that of light, that is to say, 110,000 miles per second. The energy which this implies is almost inconceivable.

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"Sir Oliver Lodge, in his New York lecture on the atom last winter, endorsed the statement made by another English physicist that the energy in a gram of radium, if it could be instantaneously released, is sufficient to blow the entire British fleet out of the North Sea onto the summit of the Scotch Mountains. Even the Alpha radiations, which have a speed of only 10,000 miles per second, if instantaneously released from a gram of matter, would develop 6,800,000 horsepower. This energy is called intra-atomic energy. According to Professor Thomson's calculation a gram of hydrogen has sufficient of this energy to lift a million tons through a height exceeding one hundred yards.

"Dr. Gustav Le Bon, who claims to have been the first to discover intra-atomic energy and to have coined this name-phrase, expresses the work which this energy is capable of doing in this way: 'Let us suppose a small bronze sphere weighing one gram. Let us suppose that it rotates in space around one of its diameters with an equatorial speed equal to that of the Beta particles in radium. It would exceed 1,800,000,000 kilogrammetres and represents the work done by 13,500 locomotives in one hour.'

"Professor Rutherford says the energy manifested in radioactive bodies is perhaps a million times greater than that produced by the various known reactions of molecular forces, and he adds, 'It seems probable that intra-atomic energy is general and of equal force in all bodies,' thus confirming Le Bon's statement to the same effect. This intra-atomic energy is probably the source of all other known forces, notably electricity and solar heat.

"Now that the fact of the existence of this colossal atomic energy has been demonstrated beyond all possibility of doubt, it will be the further work of science in the immediate future to discover some method for its liberation which can be practically applied to doing the work of the world. That it will succeed in this I have no shadow of doubt. And when man has his hand on the lever controlling this force he will be in possession of the major physical factors of our existence. What will be the effect on the material, moral and spiritual condition of mankind? That, as I have several times intimated, will depend entirely on how the world decides this power shall be used.[1]

* * *

"But I have still to mention another remarkable discovery concerning atomic structure which may also have very far-reaching effects on the future life of mankind. The transmutation of metals was the dream of ancient chemistry. There are eminent scientific men who believe we are well in sight of a possible realization of that old dream. Professor Sir Ernest Rutherford, formerly of McGill University of Montreal, and now of Manchester University, England, and Professor Frederick Soddy of Oxford have perhaps been most prominent in developing and elucidating phenomena which have grown out of the discovery of radium and radioactive substances. Very early in their experiments they found that one result of the continuous outpourings of radiations, and the consequent dissociation of the atom, was the formation of new elements. A few moments ago I called your attention to the fact that the nature of the atom, that is, as to whether it is an atom of radium or thorium, silver or gold, lead or mercury, depends on the number of electrons which it contains. According to Soddy, the number of electrons in the different elements is a little less than half the numerical value of the atomic weight. The theory of the dissociation of the atom is that those electrons which are nearest the central nucleus or sun of the atomic system are revolving with much greater rapidity than those in the outer orbits. As these inner electrons are drawn nearer the nucleus, the speed increases until it reaches a velocity of 110,000 miles per second, or more, when it leaves the system. Now, the atom which has lost an electron is not the same substance that it was before.

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[1] Dr. Williams delivered this address on July 12, 1920. *The Literary Digest* of November 15, 1924, quotes from a report made for the *New York Times* of a meeting of the American Chemical Society, in which Dr. Gerald L. Wendt, Dean of the School of Chemistry and Physics at Pennsylvania State College, says that recent experiments made by him give "reasonable promise" that he will discover the great secret and succeed in utilizing it for the benefit of mankind. After describing some of the experiments on which this hope is based Dr. Wendt adds: "If I succeed in my endeavors, it will mean the revolution of civilization."

"According to Rutherford and Soddy, the end products of the dissociation of radium and uranium are helium and lead. This process is constantly taking place naturally and no method is known whereby it can be hindered or retarded. Elements are thus passing out of existence and new ones are being formed by processes of nature. In the white stars, those which are hottest, there are the fewest elements. There are more in the yellow stars, and still more in red ones, in which the temperature is lower. There are, I believe, about thirty-six in our sun, while the earth, as you know, has some eighty elements. In an article published in the *Aberdeen University Review* in February 1917 Professor Soddy, after calling attention to the fact that gold in Mendelieff's Periodic Table is followed, without gaps, by mercury, thallium, lead and bismuth, gives this theoretical recipe for producing gold from the baser metal. He says:

" 'To get gold from mercury, expel from the atom of mercury one *Beta* particle or electron, which will make thallium, then one *Alpha* particle, which will turn the thallium into gold. Or, to get gold from lead, expel from the atom of lead one *Alpha* particle, which will turn it into mercury, and proceed as before.'

"Please keep in mind the fact that these statements are made by the foremost scientific men of our time and also remember that Sir Isaac Newton, Sir Humphrey Davy, Faraday and many other eminent men of science have announced their belief that the transmutation of the elements would some day be realized. Edison has said that this discovery might come any day.[1] . . .

"While the discovery of the dissociation of the atom destroyed the main foundation of materialism, another great prop, the doctrine of the conservation of energy, is being undermined by the same evidence that has led to the great change in thought concerning the nature and structure of matter. The discussion on this subject approaches the present ultimate reaches of human thought. As no rational concept can be formed of anything entirely outside of human knowledge and experience, and as the only mental picture we can form of energy is based on our personal experience of effort, which is the result of the exercise of will, it would seem that we are logically bound to regard all exhibitions of energy in nature as manifestations of cosmic will. And, furthermore, as all of our will activities are guided by intelligence, and as there can be nothing in us which is not to be found, at least potentially, in the cells, molecules and atoms of which we are composed, we are also logically bound to conclude that the fundamental attributes of nature are Will and Intelligence.

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[1] Just as this book goes to press, more than four years after Dr. Williams in this address called attention to the production of gold from mercury as a scientific possibility, comes the announcement in the press that this has actually been accomplished by Prof. Adolph Miethe, at the Charlottenburg Technical College, Berlin, and that Prof. H. H. Sheldon of the Department of Physics, New York University, will attempt, under the auspices of *The Scientific American*, to repeat the experiment and at the same time to ascertain the cost of producing gold in this way.

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"We may just as well face the great facts, cut this old Gordian knot and place ourselves squarely alongside the evidence which everywhere greets the seeing eye and the hearing ear, that the energies of nature are born of Infinite Will and are being guided by Infinite Intelligence toward definite ends. Led by this noble conception, science may throw off the shackles of materialism and go forward in high confidence that its greatest triumphs lie in the future.

"The ingenuity that scientific men have displayed in their attempts to account for movements in matter is astonishing. In view of the fact that all of these inventions are pure hypotheses, why not take the most simple, logical and evident hypothesis? Why is not the word 'intelligence' the best possible term to apply to the activities of the lower as well as the higher forms of life? They perform the essential functions of their existence *because they know how to do it.* The germ cells of an oak tree develop into an oak and the germ cells of human beings develop into men and women *because they know how to do it.*

"By what form of logical reasoning can such a proposition be refuted or discredited? Whence comes man's intelligence? By what absurd gymnastics of the reasoning faculty has man convinced himself that he has acquired intelligence while denying that there is any intelligent direction of matters outside of himself? Is not such an assumption a dogmatic declaration of the spontaneous generation of intelligence in man by those who deny the possibility of spontaneous generation in the lowest forms of organic existence?

* * *

"Suppose, then, that we start with the bold proposition that all forms of matter exhibit an intelligence requisite to the performance of the functions established in those forms—Infinite Intelligence conditioned down to the most elementary expression, but coordinating all forms of expression in the vast, onward sweep of cosmic evolution.

"Even Haeckel, the ablest modern advocate of pure, unadulterated materialism, found it necessary to a rational understanding of the nature of matter and force to predicate intelligence of the elementary forms of matter. Here are some of his own statements on this profoundly interesting subject:

" 'The two fundamental forms of substance, ponderable matter and ether, are not dead, and only moved by extrinsic force, but are endowed with sensation and will, though naturally of the lowest grade. Every shade of inclination, from complete indifference to the fiercest passion, is exemplified in the chemical relation of the various elements toward each other.' After giving illustrations of 'this fundamental unity of affinity in the whole of nature' he adds, 'On those phenomena we base our conviction that even the atoms are not without a rudimentary form of sensation and will.' Haeckel got God out of the universe, as he claimed, by endowing the supposed eternal atoms with the potentialities of all will and intelligence. But now that we know the atoms are created, what becomes of Haeckel's philosophy?

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"Substituting the idea of a universe *in*filled with intelligence and moving toward definite high moral ends for the doctrines of blind chance and endless but purposeless movements, let us now return for a few moments to the subject of the evolution of organic life and the struggle for existence to see if we cannot also find in this field evidence for a new and far more satisfactory view of the part which science is to play in human progress. Struggle for existence there surely is—let us not minimize that fact in the least. And I think the first thing to be said about it is that, so far as we can see, the method of struggle and survival of the fittest was the only way in which a world of life of unending progression could have come into existence. The only other alternative is the old theological idea of a world created by fiat, perfect from the beginning. But the moment we begin to examine such a proposition its absurdity and impossibility become evident. It is only by comparison between more and less that we can form judgments about anything. And it is only by the continuity of changing circumstances that we have consciousness. A perfect world would really be a changeless world, and a changeless world would be a dead world.

"Our earth may not be the 'best of all possible worlds,' but it is the only one that we have a chance to know much about, and our first business is to understand it as well as we can. When we set about doing this in a determined manner, freeing our minds from false teaching as completely as we can, we shall see that there are, and have been from the beginning, other forces at work in the evolutionary processes, which, regarded from the standpoint of ends, are of greater importance than the 'struggle.'

* * *

"Cooperation is of vastly greater importance for the development of life than competition. The conditions necessary for the first human life were made by the cooperation of all preceding life acting for millions of years, and the continuance of that human life, its fullness and completeness, was conditional on its adjustment to or cooperation with all the laws of its environment. And more than that, as Professor Henderson of Harvard has pointed out in a work which immediately arrested the attention of all scientific men, the adaptation of the environment to the organism is a no less important and significant fact than the adaptation of the organism to the environment.

"What really impresses us the moment we begin to penetrate beneath the superficial aspect of things is not a one-sided relationship between the organism and its environment in which there is a constant struggle for adaptation, but a marvelous adjustment of the one to the other with just struggle enough to stimulate the will to live to its highest and fullest expression. We are constantly losing sight of the fact that harmonious activity rather than struggle is the highest expression of life.

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"Natural selection and survival of the fittest are expressions of nature's constant striving for a fuller and higher life, but natural selection is the instrument of cooperation. A healthy human mind in a healthy human body is the perfect symbol and expression of organized society at its highest and best. A human being in perfect health has no consciousness of internal struggles. The harmonious cooperation of the individual cells makes for the perpetual joy of the whole being, and the only sense of struggle or effort is for a fuller and more active life. Think of the survival value, the conquering power, of a nation in which all of the individuals are maintaining the harmonious relations of that perfect cooperation which we see in the individual cells of a healthy human body.

"Those families, tribes or nations in which the feeling of solidarity is strongest, in which union for mutual aid is most highly developed, have in these conditions the surest guarantee of safety and continued existence.

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"Natural selection, acting on these conditions, insures the survival of those who are strongest in the moral qualities of cooperation and devotion of the individual to the general good. Conscious cooperation begins with the lowest forms of organic life and is one of the first expressions of intelligence.

"Those who have studied the protozoa under the microscope are familiar with phenomena which illustrate not only cooperation but also altruism or the struggle for the life of others. The Radiolaria, for example, prepare the particles of sand which are to serve as the inorganic matrix of the shells of the daughter cells and these particles of sand are exuded immediately on the division of the mother cell. There, at the very beginning of organic life, are seen the promise and potency of all that is fine and noble in giving something of life for others.

"The function of the white blood corpuscles in the human body is another instance of pure altruism in the cell. They are always ready to sacrifice their individual lives for the good of the organism.

"As we rise in the scale of life, increasing intelligence increases power over environment. That is a fact of the greatest importance and one to which far too little consideration has been given by scientific writers. The plant has very little power over its surroundings; the animal has much more. The whole long record of the advance of man, from the earliest prehistoric times to the present, is the history of his increasing power over his environment by the acquisition of a knowledge of nature, of natural laws, or, in other words, of scientific knowledge.

"More and more survival power has been transferred from the physical to the psychical plane, from body to mind. Man increased his power over wild animals by the invention of weapons; he increased his power over climate by constructing shelter, by making garments and by the use of fire; by the use of fire and the cultivation of wild grains he greatly increased the range and digestibility of his food supply.

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"Scientific writers, with very few exceptions, seem to have lost sight of the revolutionary change in the relation of the organism to its environment which growing intelligence gives. It means that in a very large degree man is master of his own destiny; it means that he may himself largely control and direct his own further evolution. Man's physical evolution was practically completed in prehistoric times, with the exception of brain tissue. The evolutionary processes may continue there for a very long time. That eminent neurologist, Dr. Ramon Y. Cajal, says that the human brain is capable of almost indefinite increase in complexity of function. He calls attention in great detail to the way in which progressive evolutionary and also degenerative changes come about in the brain tissue. He points out the anatomical reasons for the rise and fall of nations and lays the first solid foundation that we have ever had for rational, progressive education in the structure of the brain itself, the organ of the mind. The revelation is full of a great hope, but it is also an appalling analysis of the physical reasons for our present shortcomings.

"It was the mind-difference between man and his nearest animal relative, the ape, which led Owen to place him in a separate order. Wallace is in substantial agreement with this view, and so is Mivart, who says that the difference, from the mental point of view, between man and the ape transcends the difference between ape and blade of grass. Fiske says, 'I should be disposed to go further and say that while for zoological man you can hardly erect a distinct family from that of the chimpanzee and the orang, on the other hand, for the psychological man you must erect a distinct kingdom; nay, you must dichotomize the universe, putting man on one side and all things else on the other.'

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"Nature has produced her masterpiece, man, and it is her design to perfect him, to lift him to a place far above any standard that exists today. And this design does not involve any breach of continuity in the cosmic processes. Cooperation and altruism were in nature from the beginning. From these principles was born the family; out of the family came the tribe and the clan, and from these modern society was developed. If, therefore, we find a system of ethics, a consciousness of moral obligation, in existence today, the sanction for that must be found in the evolutionary processes of nature. Spencer, in reply to Huxley's Sheldonian Lecture in 1893, says: 'If the ethical man is not a product of the cosmic process, of what is he a product?'

" 'Subtract from the universe its ethical meaning,' says Fiske, . . . 'and nothing remains but an unreal phantom, the figment of false metaphysics.' And he adds this eloquent and beautiful passage: 'I think it can be shown that the principles of morality have their roots in the deepest foundations of the universe, that the cosmic process is ethical in the profoundest sense, that in that far-off morning of the world, when the stars sang together and the Sons of God shouted for joy, the beauty of self-sacrifice and disinterested love formed the chief burden of the mighty theme.'

"And that is the theme on which science must work for the further evolution of man. Here is the outlook, inconceivably grand beyond the loftiest imaginings of a century ago. If you would have a vision of the possibilities of human progress during the next hundred years, let us say, then keeping in mind the fact that invention, discovery, everything that is included in the term 'scientific advancement,' has been after the manner of geometrical progression, remember that the discoveries that have been made within the memory of men now living are of greater significance with reference to human progress than all that has been learned before that time.

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"Compare the world of today with that of six thousand years ago and then imagine, if you can, a greater change taking place during the coming century and you will have a vision of what the world may be in the year 2020. What is the man of today going to do with this outlook? Will he ally himself with the forces of nature, with the fundamental laws of the Cosmos, and develop an ethical system in which cooperation and altruism and an intelligent control of his own great destiny shall supersede belief in blind chance and the selfish struggle for the superficial things of life? If he wills to do this, then, as Emerson says, the very sticks and stones of the earth, the very lowest as well as the very highest in nature, will work with him and for him.

"Nature, or, as I should prefer to say, God through nature, speaks to men with a thousand voices that are always saying: 'It is my will and desire that you have larger and fuller life. To this end was everything created that has been made.'

"Humanity seems to me like a man standing on the borders of a great inheritance which is his by right of descent but with hardly any realizing sense that he may enter in and possess it. He realizes his growing control over cosmic forces, but is this growing control bringing a larger and fuller life to mankind as a whole? Science has taken the place of the gods and is bestowing far more valuable gifts upon man than were ever asked of the ancient divinities.

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"What is man going to do with this rapidly increasing power over the unlimited resources of nature? How are the knowledge and power to be applied for the betterment of humanity and to assist in the further evolution of man? Two great forces, the constructive and the destructive, are contending in the world today as they have always been contending. The battle line sways back and forth. The constructive forces have always won in the past, and they will probably win now and in the future. But many nations and forms of civilization have gone down in the great struggle, not because it was inevitable but because they disregarded the laws and conditions necessary to their continued existence.

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"What is to be the fate of many of the nations of today? Of our nation? There are, as I said at the outset, many disquieting signs.

A View of the Kennebec from Dr. Williams's Residence.

From a photograph colored by Mrs. J. Leon Williams.

"Dr. Nicholas Murray Butler, President of Columbia University and one of the candidates at the recent Chicago Convention for the highest office in the nation, has recently published a book with the title, *Is America Worth Saving?* Coming from so eminent a man, that is a rather arresting question. Presumably he considers the question open to discussion.

"Many other volumes have recently appeared filled with pessimistic predictions as to the future. But, as I said at the beginning, I am an optimist, not because of what I can see immediately in front of me but because of my belief in the force that is moving just behind this present confusion and wrack of things, just behind the curtain of sense.

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"A thousand patent-medicine remedies, a thousand fads are urged as cure-alls for the evils that are upon us. But science knows nothing of all this. Science is the wise surgeon who says the knife must go to the seat of the trouble, and the one great trouble today is the same that led the nations of Europe into the Dark Ages—wrong education.

"*The Boston Globe,* in a recent editorial on college and school commencements, asked a question which was substantially this: 'What is the meaning of a system of education which teaches young men and women fine ideals and then turns them loose into a world where all of those ideals are speedily crushed?'

"I have read a dozen articles by college professors during the past year in which present educational methods are severely criticised. But something far more fundamental is needed than mere tinkering with our present educational system.

"The mad race for speedy wealth; the almost complete indifference to beauty of life, which is the greatest of the arts; the contempt for honest work of the hands thoroughly done; colossal self-conceit; bumptiousness and bluff; the great art of advertising things which are never delivered—these conditions must give place to a real reverence for genuine learning and a love for beauty in every aspect of life. A respect for honest work with a demand for it is one of the surest tests of the moral status of any people. Judged by that test, the moral standards in this country are low. A new foundation in the hearts of the whole people must be laid before we can begin to reform our educational system. The scientific attitude of mind which was characteristic of the great Greek teachers, the willingness to see straight, to look all the facts squarely in the face and to be governed in conduct according to those facts, must, in the words of Sir Francis Galton, 'be introduced into the national conscience like a new religion.'

"In truth, a new religion in which the fundamental principles of science are united to the highest manifestation of the cosmic process that has yet appeared, the lofty ethics of the Founder of Christianity, that system of ethics which materialism, in and out of the Churches, has trodden underfoot, is what we must have if civilization is to be saved, or if there is to be saved whatever in it is worth saving.

* * *

"The old order is ended—let us make no mistake about that. The poets have the clear vision; here is what a modern British poet sees:

The old times are dead and gone and rotten;
The old thoughts shall never more be thought;
The old faiths have failed and are forgotten,
The old strifes are done, the fight is fought;
And with a clang and a roll, the new creation
Bursts forth, 'mid tears and blood and tribulation.

"But tears and blood and tribulation are not an end; they are the price paid for knowledge of the law, the law that no nation or no individual lives to itself. The deeper significance of strife is not destruction, but a higher life.

"We have seen that the working of those fundamental principles of evolution, cooperation and altruism produced the family, the tribe, the nation. The next great step is the union of all the nations of the earth in a league to prevent the selfish struggle for supremacy. That way lies the further evolution of man, and not only are all who are working against that great effort working against the higher interests of humanity; they are working against the inevitable laws of the Cosmos.

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"Never since that far-off time when some dim vision of future destiny floated before the mental eyes of primitive man has there been such an opportunity for a great world teacher and leader as today. Never has any nation had such an opportunity as America has today. The unrest, the agitation, the anarchy which is so disturbing and alarming the many politicians and the few statesmen, is the surging-up, under the stimulus of a great and growing power of determination, that all of those human qualities which do distinguish man from the brutes shall have free play in an environment in which no individual soul shall be fettered by unjust conditions of life. This great power, which is making itself increasingly felt, can be led, controlled, directed only by great leaders. If such leaders appear, will the powers that be crucify them? Shall we have to pass through a deluge of blood and fire before we learn the great lesson that the history of human evolution teaches? I do not know, but this I do know: the first race or nation to realize fully that the chief and only national concern is the production of strong, healthy, intelligent, self-controlled men and women, free to do the best that they can with a freedom protected by laws justly executed, with power to give effect to its will that the greatest things shall come first—*that* people will become the ruling power of the earth and its leaders will direct and guide the continued evolution of humanity."